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TRUNK-HUNTING CONNECTORS IN STROWGER AUTOMATIC SYSTEMS

By KARL F. STEINHAUER

***SYNOPSIS:** Requirements of multi-line subscribers—basic problems of trunk hunting—present basic P.B.X. connector—night service connections—traffic studies—serving more than ten trunks—various expedients—level-hunting connectors—avoiding mixed numbering—the needs of small offices—miscellaneous services.*

TECHNICAL and non-technical literature abounds with elementary treatments of the Strowger connector as it is employed to select the terminal number of a called subscriber having but one telephone line. Descriptions of a multitude of party-line ringing schemes testify that the versatile Strowger connector is not limited to single-station operation, but is equally well suited to multi-station shared party-line service. Literature is scant, however, on the several equally ingenious adaptations of the Strowger connector to the requirements of subscribers, each of whom, rather than sharing a line, has the exclusive use of several lines. It is the purpose of this article to review the basic requirements of such subscribers and several connector arrangements which have been devised to meet them.

Each multi-line subscriber usually has a switchboard of its own, to which are brought the "outside" lines or *trunks,* and also the station lines of the internal organization. Thus the subscriber has a *private branch exchange* (abbreviated P.B.X.), the trunks and stations of which can be interconnected as required. There are also many multi-line subscribers, exemplified by certain types of retail stores, wherein the subscriber does not use a P.B.X. switchboard, but merely has a number of order-taking telephones, each having its own line from the central office.

The equipment of the operating telephone company should not compel a calling subscriber to try dialing successively a series of scattered or consecutive directory numbers, all serving the same multi-line subscriber, in an effort to find an idle trunk or line. The basic standard adopted for such service is that the directory should list but *one telephone number* for the multi-line subscriber, in which case the central office must be so equipped that if this directory-listed number is dialed, and is busy, *the connector will take the initiative to hunt for an idle line* amongst the remaining circuits to the called establishment. This requires, of course, that the several lines must be connected to adjoining or consecutive bank-contact positions.

The requirements in the preceding paragraph are relatively simple, and probably account for the cursory treatment given trunk-hunting connectors in generalized telephone literature.

The problems and circuit variations in automatic operation arise from four questions:

1. How shall the consecutive-line *group* be *marked* in the connector banks?

2. Shall the connectors hunt during the hours the P.B.X. switchboard is *not* attended, and "night connections" are set up?

3. Does any P.B.X. subscriber have *more* than the *ten* trunk lines which represent the normal capacity of one level of a connector-switch bank?

4. Does the operating telephone company have enough multi-line subscribers to warrant assigning a whole special connector group to them?

This article will treat these four questions in the above order.

Ordinary Present Practice

A P.B.X. group bank-marking circuit pattern developed in 1918 was so well conceived that it continues in use today in many Strowger trunk-hunting connectors. A fourth lead, the "extra control" lead, abbreviated *EC,* is required for each line in the trunk-hunting connector banks. Control lead *C* and extra control lead *EC* are strapped on all lines in a P.B.X. trunk group, except the last line in the group. For the five lines in Figure 1, this is shown schematically in Figure 2. The task of strapping leads *C* and *EC* is actually simpler

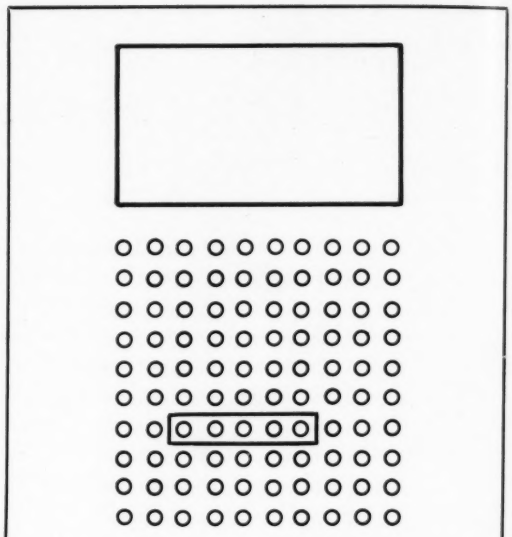


Figure 1. Five consecutive line numbers (43, 44, 45, 46 and 47) in the banks of a Strowger switch.

than the schematic of Figure 2 suggests. Both leads are multipled throughout all banks on a shelf, and the strapping is done at the shelf bank terminal block, only once for each line.

The trunk-hunting feature of these connectors usually requires two additional relays in each connector: if the regular connectors in the central office have eight relays, the trunk-hunting connectors will have ten relays. If any line (such as 43, first in the group in Figure 1) is dialed and is idle, the connector seizes the line in the usual way, namely, by grounding lead *C* to operate the cut-off relay of the called line. Because leads *C* and *EC* of line 43 are strapped, in grounding lead *C* the connector grounds also lead *EC* at every bank multiple appearance of line 43. If, now, another subscriber dials line 43, during dialing of the last digit, 3, the second connector tests lead *C* of line 43 and finds it busy. Lead *EC* being grounded, relay-interrupted rotary stepping takes place. During this automatic rotary stepping, the connector, seeking an idle line, looks for *absence of ground* on lead *C,* and each grounded contact *EC* causes another rotary step to be taken. If all lines in the group are busy, the wipers step to the last line in the group. There lead *EC* is open so

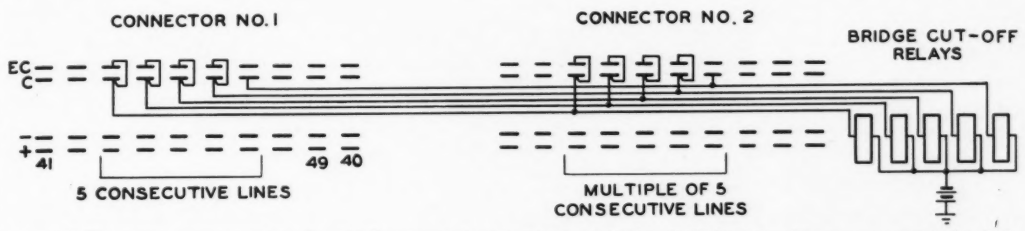


Figure 2. The most common pattern for 100-line connectors. Leads C and EC of all lines in the group, except the last, are strapped.

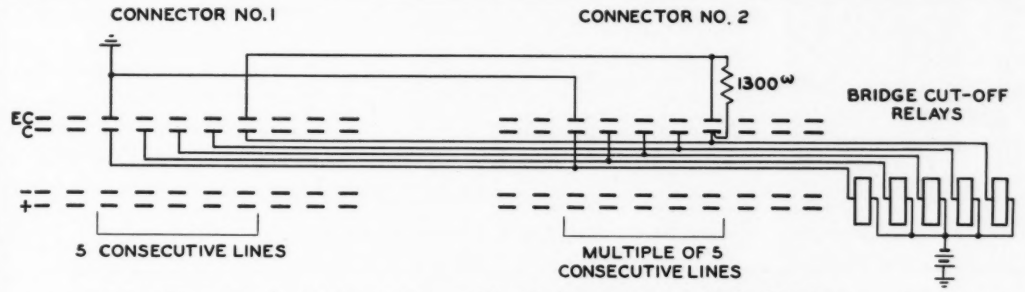


Figure 3. The pattern for 100-line connectors with night-line service and for level-hunting connectors.

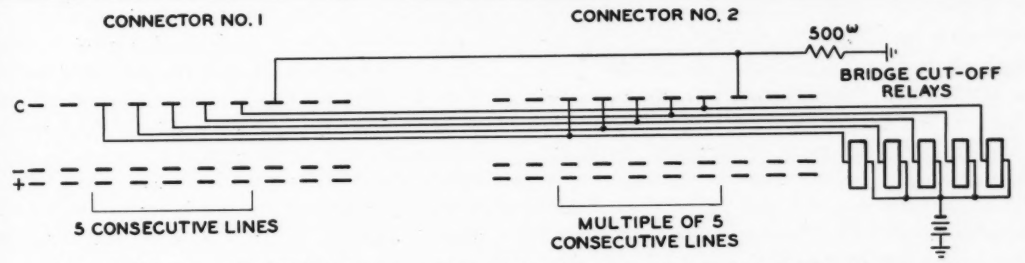


Figure 4. The pattern for 200-line connectors. No special marking on any line used for telephone conversations.

no further steps are taken, and ground on lead *C* causes busy tone to be returned to the calling party.

Night Service

Let us now assume five o'clock has come, the "night connections" shown in Figure 5 have been put up, and the P.B.X. operator has gone home. A call to 43 will ring the night watchman, who can inform callers that the establishment opens at such-and-such time the next morning, can give out home numbers for urgent calls, etc. If, however, two calls are made to 43 in close succession, the first will busy 43, the connector for the second call will hunt past 43 and ring 44, and perhaps no one will answer. Again, perhaps the manager is working after hours, and has told people he can be reached during the evening on 44. If meanwhile he calls out, busying 44, a call to 44 finds the line busy, the connector hunts past 44, and 45 will be rung. The station on line 45 probably is in another part of the building and goes unanswered, or is answered by the shipping clerk who must ask the caller (who may be at a paystation!) to hang up and call again later. Inasmuch as night calls are infrequent, little difficulty actually arises, and for 32 years most operating telephone companies have found the system of Figure 2 entirely satisfactory.

If the problem locally is serious, however, two

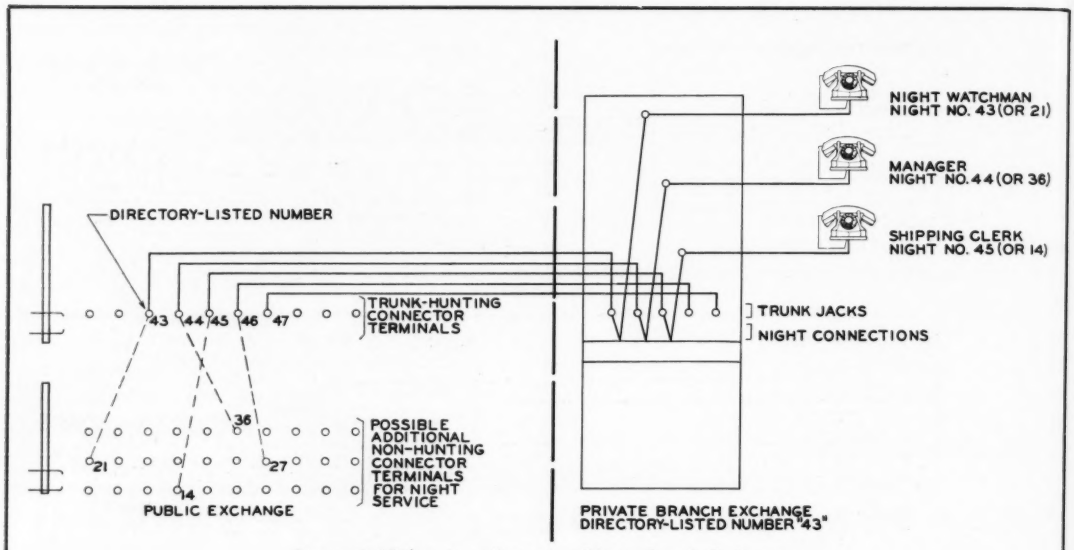


Figure 5. Night connections at a Private Branch Exchange.

solutions are possible. Simplest is the case of just one individual who works overtime frequently, and wishes his callers to get busy tone when his telephone is in use; he should be plugged into the last line in the P.B.X. trunk group, 47 in Figure 5. But perhaps several people work after hours in widely separated departments, as in the above example. In this case the operating telephone company should assign an additional connector terminal to each line requiring night service. The second set of numbers can be assigned at random. The line and cut-off relays of the second terminal numbers should be disconnected. If the second numbers are on a trunk-hunting connector shelf, none of their leads *C* and *EC* are strapped. Thus all the second numbers appear in effect as the last line of a one-line group, and, if busy, cannot cause hunting, but will return busy tone. Again using Figure 5, if the manager dials 21 from his home, he is sure either to ring the night watchman or to hear busy tone. If the manager tells people to call him on 36 at night, they will get him or busy tone; they will never get the shipping clerk. However, the telephone company must give up two sets of numbers, perhaps from limited facilities, and each P.B.X. station user must ask his most frequent callers to remember two dissimilar numbers, or have a separate night listing in the directory.

The limited suitability of Figure 2 to night service led to the introduction in 1932 of the bank-marking circuit pattern of Figure 3. This, too, uses a fourth bank contact and extra control lead *EC,* for each P.B.X. trunk line. The first line in a trunk group always has ground on lead *EC.* Subsequent lines in the group have lead *EC* open, except the last line in the group which has a 1,300-ohm resistor permanently connected between leads *C* and *EC.* Figure 6 shows a typical method of mounting the resistors.

The bank wiring of Figure 3 usually requires three additional relays in the connector: if the regular connectors in the central office have eight relays, the trunk-hunting connectors will have eleven relays. If any line (such as 43, first in the group in Figure 1) is dialed, and is idle, the connector seizes the line in the usual way, namely by grounding lead *C* to operate the cut-off relay of the called line. If now another subscriber dials line 43, during dialing of the last digit, 3, the second connector tests lead *C* of line 43, finds it busy, and then tests lead *EC.* Lead *EC* being grounded, relay-interrupted rotary stepping takes place. During this automatic rotary stepping, the connector operates on the *battery-searching* principle, looking for negative battery through the

unoperated cut-off relay of an idle line. If all lines in the group are busy, the wipers step to the last line in the group. There, ground (from lead *C*) through high resistance (1,300 ohms) marks lead *EC* to prevent further steps, and the ground on lead *C* causes busy tone to be returned to the calling party.

Comparing Figure 2 and Figure 3, we notice that in Figure 2 lines in the middle of a group are marked the same as the first line of a group, and cause hunting, whereas in Figure 3 lines in the middle of a group lack marking, just as do lines not in a group, and cannot cause hunting. Thus, if any line in the group except the first is dialed, the connector wipers have no opportunity to come to rest on the first line, and the connector does not set itself for hunting. If a caller dials directly any line (other than the first) in a group, he will either ring the line number he dialed, or will hear busy tone; the connector will not attempt to complete his call over another line in the group.

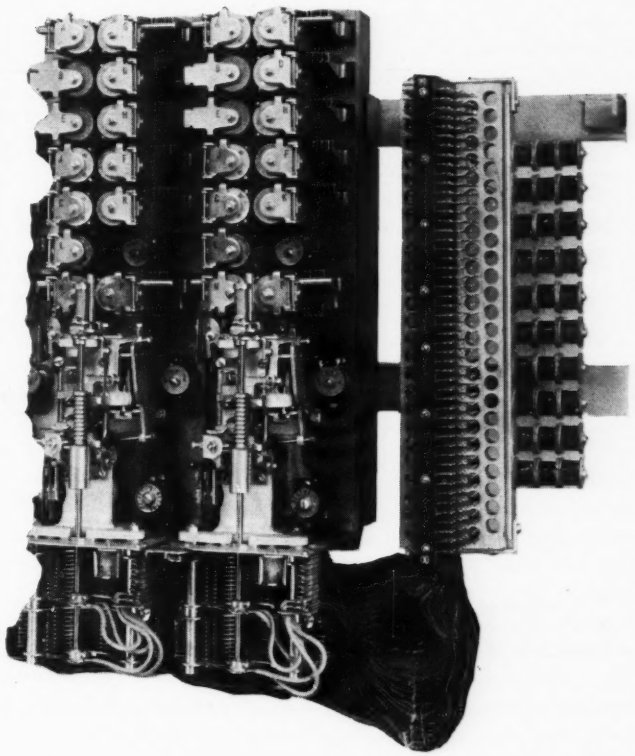


Figure 6. A typical method of mounting, on a connector-shelf bank terminal block, the resistors for the bank-marking pattern of Figure 3. The connectors shown, being at the right-hand end of the shelf, are combination local-and-toll connectors, having two more relays than the minimum of eleven, mentioned in the text, for local trunk-hunting connectors.

This sort of connector is recommended where special attention to night service is desired, as all terminals of the group except the first one may be used for night listing. It is sometimes referred to as a "night-service" or "pilot-number" connector. If the caller dials the regular directory-listed "pilot" daytime number, and it is busy, the connector sets itself to hunt; if any other number than the first in the group is dialed, as at night, the connector will not hunt. Such connectors make unnecessary the assignment of the extra terminals shown dotted in Figure 5.

Traffic Studies (Overflow Metering)

The P.B.X. subscriber and the telephone company both hear occasional reports of repeated attempts by outside subscribers to call the P.B.X., with the caller receiving busy tone time after time. Too often actual statistical facts are lacking, and the number of P.B.X. trunks utilized is determined subjectively or by guesswork.

The telephone company can render valuable service to P.B.X. subscribers, and perhaps prove the need for more trunks, thereby increasing its own revenue, by taking occasional observations of the exact number of attempted calls which fail to reach the P.B.X. because all the P.B.X. trunk lines are busy. Such a count is called *overflow* metering. It is very simple to do, either with connectors using Figure 2, or with connectors using Figure 3.

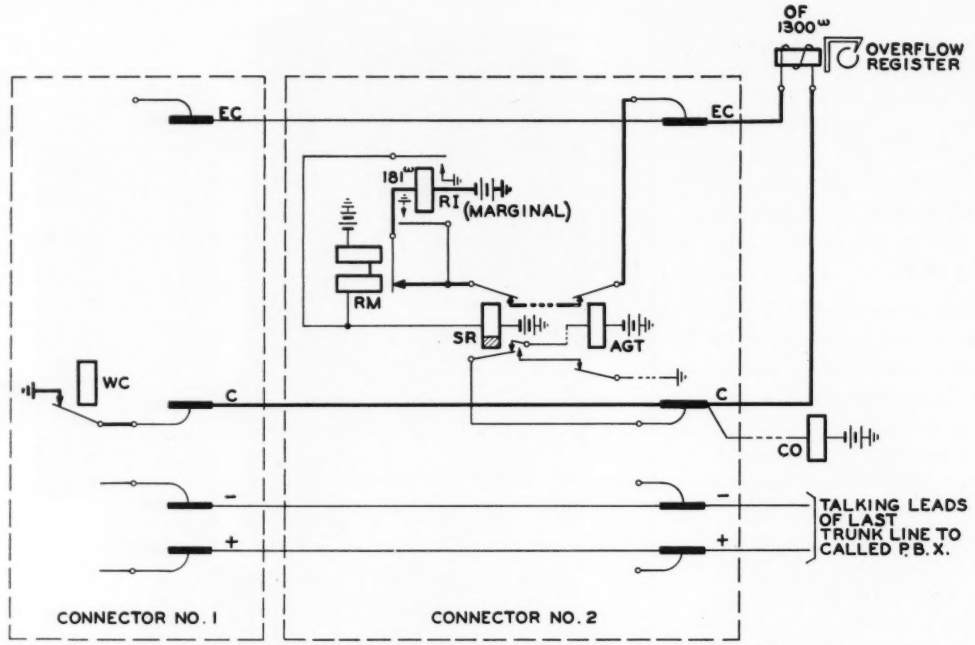


Figure 7. Overflow metering, for counting calls to P.B.X. on which calling party receives busy tone. Registration occurs during release of slow-to-release relay SR.

In Figure 2, assume that a traffic register (sometimes called a "service meter") is bridged between leads *C* and *EC* of the last line of the group. Assume that all lines in the P.B.X. trunk group are busy, and an absence-of-ground-searching connector comes to rest on the last line of the group. The condition at this moment is shown in Figure 7. For a fraction of a second (until slow-to-release relay *SR* releases), current flows through 181-ohm relay *RI* and through 1,300-ohm register *OF* in series. The 1,300 ohms prevent marginal relay *RI* operating, but register *OF* operates, counting one overflow call. When relay *SR* releases, it disconnects relay *RI* from lead *EC*, releasing register *OF*. Lead *EC* now is clear, ready to receive registration of any additional uncompleted calls attempted while the all-trunks-busy condition continues.

In Figure 3 the 1,300-ohm resistor between leads *C* and *EC* of the last line in the group can be replaced with a 1,300-ohm traffic register, to obtain, in a similar manner, overflow registrations when all trunks are busy. Thus overflow can be counted simply by a register mounted and wired either permanently or temporarily. All other apparatus and wiring are already inside standard Strowger trunk-hunting connectors.

Expedients to Serve More Than Ten P.B.X. Trunks

Most telephone companies find that the trunk-hunting connectors thus far described, which search over a single level and thus can search over a maximum of ten consecutive trunk lines, are adequate for their largest subscribers. Even a moderate-sized exchange may, however, serve a large factory or a large hotel which requires more than ten trunks. Where this condition is *foreseen,* Automatic Electric Company recommends *level-hunting* connectors, discussed later in this article. For the moment, however, let us consider some of the expedients which can be adopted when a subscriber's business grows *unexpectedly* to require more than ten trunks.

Local ingenuity always, of course, evolves some workable plan. Sometimes a telephone company

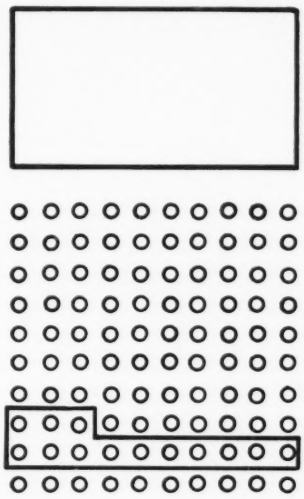


Figure 8. Thirteen consecutive-appearing line numbers must be spread over more than one connector level. Unless the connector is equipped for multi-level hunting, it will not test trunks on any level but that to which it is dialed.

does this merely by assigning two sets of unrelated terminal numbers, listing both in the directory, and advising the subscriber to show both numbers on his stationery and in his advertising. Even if the numbers seem consecutive, as might the thirteen-line group shown in Figure 8, when ordinary single-level trunk-hunting connectors are used, the terminals, being on different levels, require that, after dialing 21 and receiving busy tone, callers must hang up and then dial 31. But worst of all, the connector hunting on level 3 will have access to, and be able to test, only three trunks. The next few paragraphs illustrate and describe several methods which are considered more efficient.

One-Way Trunks

The very first expedient to give additional service to a subscriber requiring more than ten trunks is to add one-way trunks, as suggested by Figure 9. Here the subscriber has been assigned three additional trunks. Inasmuch as dialing the directory listing gives the caller access to only ten trunks, the subscriber's P.B.X. attendant is instructed to use her new circuits one way as first choice for outgoing calls from the P.B.X. This lessens the number of directory-listed trunks busied by outgoing calls from the P.B.X., so there will be more directory-listed trunks available for calls into the P.B.X.

It should suffice to instruct the subscriber's P.B.X. operator to utilize the trunk lines properly and efficiently. Where she can be relied upon to do so, flexibility results from terminating all trunk lines at both line equipment and connector terminals in the central office. For example, all the trunks would be suitable for two-way night service. If, however, problems of operator discipline or training make it desirable, it is relatively simple to make minor modifications in the central office wiring or distributing-frame jumpering which electrically compel the P.B.X. operator to use the trunks in the manner intended. These are shown in the left-hand part of Figure 9. One-way trunks incoming to the P.B.X. do not use a line relay at the central office, but only the cut-off relay, or a resistor, on the control-lead. Two-way trunks have at the central office complete line equipment, like ordinary subscriber lines. One-way trunks outgoing from the P.B.X. are connected to line and cut-off relays but, unless test, verification, and two-way night service, are desired, are not connected to any connector bank contacts (shown by dotted line in Figure 9).

Two-Way Trunks Handle More Calls

A given number of trunks can handle a larger number of calls if they are wired for two-way service, as the traffic peaks of outgoing calls usually will not coincide with the traffic peaks of incoming calls.

Two-way service, for more than ten trunks, requires that the connectors for the given hundred must, as a whole, have access to all the trunks. Where single-level trunk-hunting connectors are used, this means dividing the connector banks into sub-groups, each of which has access to part of the trunks. This is relatively easy, because traffic into a connector group which includes P.B.X.'s usually will be so great as to require installation of one or more "overflow" connector shelves. The bank contacts of all regular and overflow connectors serving a given hundred normally are multipled fully and directly together. When a

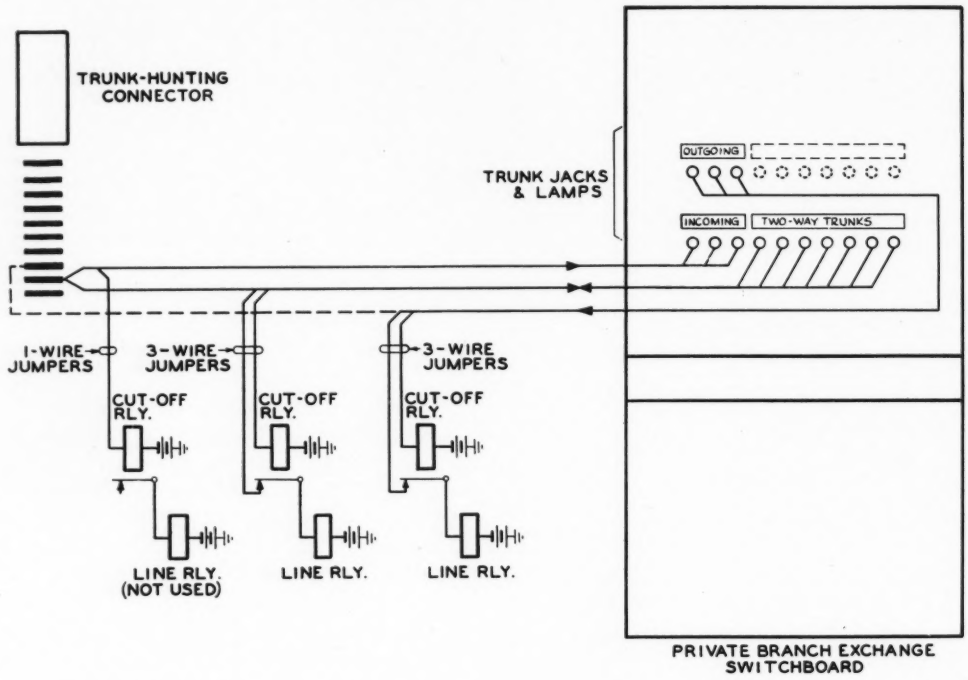


Figure 9. Private Branch Exchange with thirteen central office trunks served by a single-level trunk-hunting connector by use of some one-way trunks.

P.B.X. having more than ten trunks is served by a connector hundred, the bank contacts for those trunks in the regular shelf and in the overflow shelf or shelves either will not be multipled from shelf to shelf at all, or will be multipled specially, according to one of the plans described in the paragraphs which follow.

More Than Ten Two-Way Trunks

The simplest case is that of a twenty-line group in a central office having not only the main distributing frame but also a line intermediate distributing frame. Figure 10 shows twenty trunks accessible by dialing 421. Because of traffic scattering between preceding switches in the switch-train, a call to the twenty-line P.B.X. subscriber may come, for completion, to a connector on either the regular or an overflow shelf. As shown in Figure 10, each connector shelf has access to ten trunks, so every connector can hunt trunks with its full efficiency. Level 2 of the overflow shelf is cabled directly to the distributing frame; the other levels of the overflow shelf are multipled to corresponding levels of the regular shelf.

In Figure 10, although only ten directory numbers are used up, twenty sets of line and cut-off relays are required. These we pick up readily through the line I.D.F. At the P.B.X. switchboard, the trunk jacks can be numbered unconventionally; thus, central office bank-contact position 421 can have two jacks at the P.B.X. switchboard, 421-A and 421-B; or the jacks may be given the numbers of the terminals used for night service. If the P.B.X. subscriber requires inward night service, auxiliary connector terminals must be assigned, as was done in the lower left-hand corner of Figure 5; otherwise, inward night calls would have only a 50-50 chance to get through. The ten circuits on the regular connector shelf can be tested through the test distributor and test connector. Unless auxiliary night-service terminal

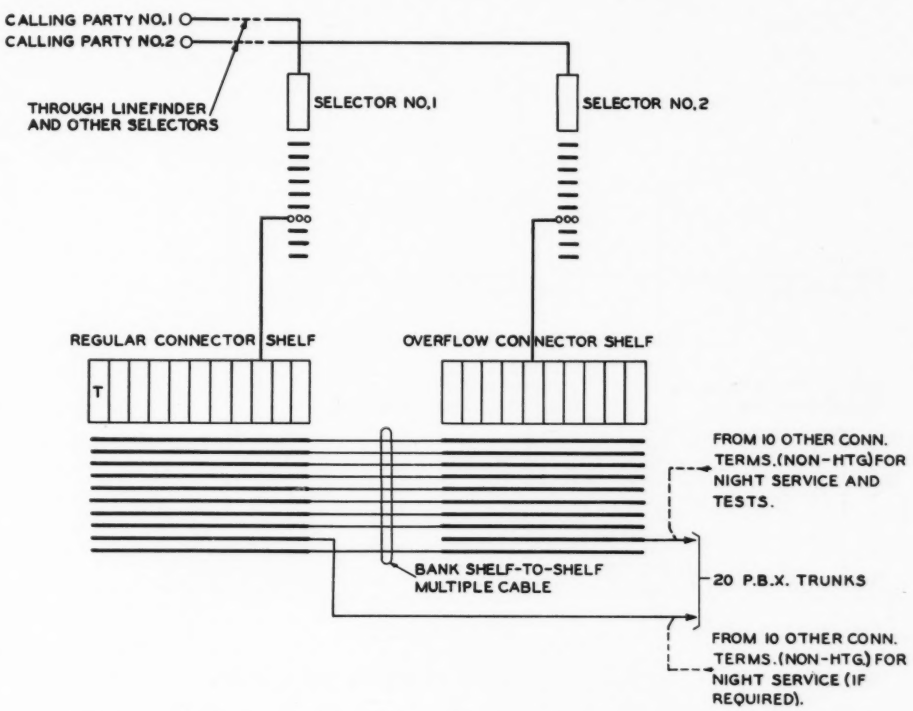

CALLING PARTY NO.1
CALLING PARTY NO.2
THROUGH LINEFINDER AND OTHER SELECTORS
SELECTOR NO.1
SELECTOR NO.2
REGULAR CONNECTOR SHELF
OVERFLOW CONNECTOR SHELF
T
FROM 10 OTHER CONN. TERMS.(NON-HTG)FOR NIGHT SERVICE AND TESTS.
BANK SHELF-TO-SHELF MULTIPLE CABLE
20 P.B.X. TRUNKS
FROM 10 OTHER CONN. TERMS.(NON-HTG.) FOR NIGHT SERVICE (IF REQUIRED).

Figure 10. Twenty trunks derived from one level by splitting the level multiple into two sub-groups.

numbers have been assigned to the ten circuits on the overflow shelf, they can be tested only through an M.D.F. test shoe. Verification service is not practicable.

But no subscriber's business grows suddenly from requiring ten trunks to requiring twenty trunks. What of the subscriber requiring twelve trunks, who does not like the one-way trunks of Figure 9, and wishes two-way trunks?

Grading

When we apply the method of Figure 10 to twelve trunks, shall we put ten trunks on the regular shelf and two on the overflow shelf, or shall we put six trunks on the regular shelf and six trunks on the overflow shelf? Neither. In either of these arrangements, at least one connector shelf has access to less than ten trunks, and its connectors cannot hunt with their full efficiency.

Figure 11 shows how the twelve trunks can be reached from a ten-trunk level on each of two connector shelves. Each connector has access to ten trunks when dialed to the directory-listed level for the P.B.X. subscriber. The first-choice trunks for each connector shelf are two trunks individual to that shelf; the last-choice trunks, the remaining eight trunks, are common to both shelves. Thus, we have now twelve outlets for this connector level. Combining individual and common trunks to increase to more than ten the number of outlets from the group is called *"grading"*.

Each extra outlet from the overflow shelf obtained by grading requires line and cut-off relays, just as does any subscriber line appearing in the banks of a regular connector shelf. It is desirable that the extra outlets also appear in the banks of a test connector.

The three principal techniques for wiring the extra outlets are:

(a) *Banks Divided into Sub-Groups, with Extra Cabling*—A practice common not many years

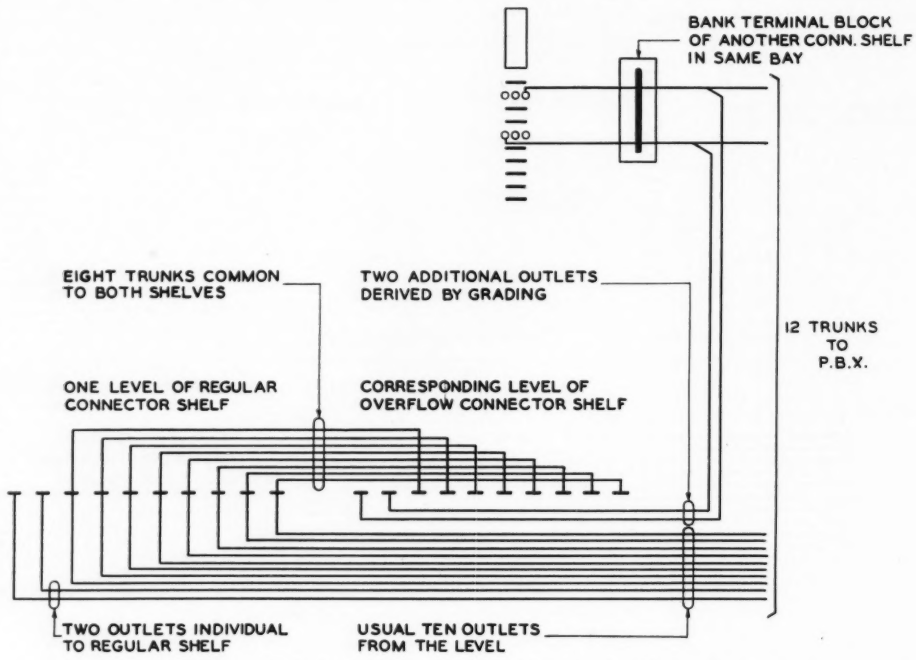


Figure 11. Twelve P.B.X. trunks derived from one level by grading.

ago, especially in central offices with a line I.D.F., was to *cable* the extra outlets from the overflow-shelf bank terminal block directly to the distributing frame. Figure 10 is an application of this method to twenty P.B.X. trunks. At the line I.D.F., line and cut-off relays are connected as required. It is advisable to connect each overflow-shelf extra outlet to another connector-bank terminal so each extra line can be tested through the test connector of some regular shelf. The regular terminal multipled to the overflow-shelf outlet serves also as a "night number" for the P.B.X. trunk line derived.

(b) *Grading by Jumpering Within the Connector Bay*—The individual outlets derived for the overflow shelf can be associated with line and cut-off relays and test and night-service terminals by disconnecting from them the usual shelf-to-shelf bank multiple cable, and running three-conductor *jumpers* from them to other bank terminals elsewhere on the same overflow shelf terminal block or (like the connections shown dotted in Figure 5) at the bank terminal block of one or more other shelves, regular or overflow, trunk-hunting or non-hunting, on the same bay. This is a simple method for a small exchange where one or two P.B.X. subscribers have grown to require more than ten trunks. Figure 11 shows this scheme.

(c) *Bank Slip, Using a Second Terminal Block on the Shelf*— Figure 12 shows an arrangement which had found considerable favor in the recent past, just before level-hunting connectors came into general use. On some overflow connector shelves which are long enough, a second terminal block, sometimes 8 by 50 just like the bank terminal block, or quite often 6 by 50, can be mounted beside the bank terminal block. To this second or auxiliary terminal block are multipled the bank contacts of the regular connector shelf. Most overflow-shelf bank contacts are jumpered straight across, multipled to the corresponding regular-shelf bank contacts. Often three-conductor jumpers are used for this straight multipling, markings required on leads *EC* being connected at the bank terminal block of *each* shelf.

Three-conductor jumpers connect the individual outlets of the overflow shelf to other than the correspondingly located terminals of the auxiliary terminal block. Each overflow-shelf individual outlet is connected in this way to a contact in the regular-shelf test-connector banks, and, through cabling from the regular-shelf bank terminal block, to line equipment and to the subscriber's trunk line.

The regular-shelf terminal for the line remains jumpered to the correspondingly located bank contacts on the overflow-shelf as well as to the overflow-shelf individual outlet, and serves as the night number for the extra outlet.

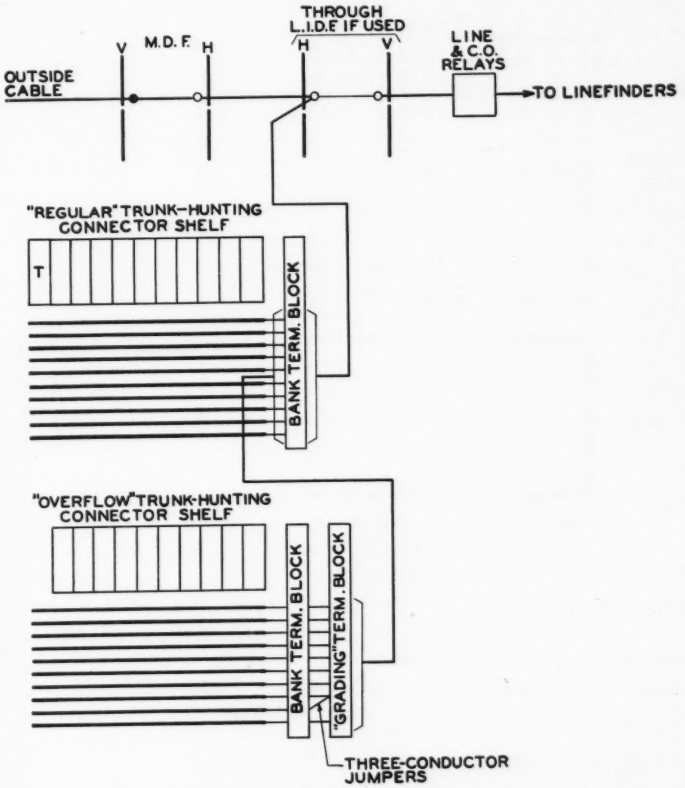


Figure 12. Wiring for deriving twenty P.B.X. trunks for one connector level as described in paragraph (c), pages 90-91.

Figure 12 illustrates twenty trunks, accessible by dialing 21 into the connectors. Ten individual outlets for level 2 of the overflow-shelf are shown jumpered to the ten lines on level 3 of both shelves. (They might equally well have been jumpered to the ten contacts of a non-adjacent level or to ten contacts scattered on several levels.) The directory-listed number, 21, thus actually gives access to the twenty circuits shown in Figure 13. The ten terminals on level 3 have no marking on lead *EC*, and can be used as the night numbers of the P.B.X. subscriber, and also as test numbers for the ten extra outlets.

Limitations of Grading Schemes

The arrangements of Figures 10, 11 and 12 for more than ten trunks improve efficiency, and make as full use of the trunks as can be obtained with single-level trunk-hunting connectors. When the directory number is dialed, any connector has access to a full ten trunks and hunts as effectively as it can, and each trunk is accessible from at least one shelf of connectors.

On the other hand, occasionally all ten trunks on level 2 of the regular connector shelf of Figure 10 or 12 may be busy while two or three trunks on level 2 of the overflow shelf are idle. In every such case, if the next call to the P.B.X. subscriber comes into a connector on the regular shelf, although two or three trunks on the overflow shelf are idle, the caller receives busy tone.

Therefore the methods of Figures 10, 11 and 12 must be regarded merely as expedients to use when a subscriber's business grows *unexpectedly* to require more than ten trunks. They give the best efficiency obtainable from single-level trunk-hunting connectors, but not the best efficiency possible from a given number of trunks. They should not be used when it is foreseen at the outset that one or more subscribers require, or soon will require, more than ten trunks.

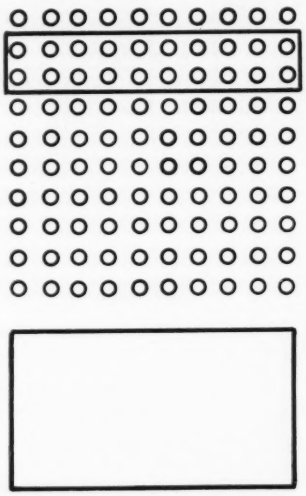


Figure 13. Twenty P.B.X. trunks grouped in connector banks, using the method of Figure 12.

Level-Hunting Connectors Give Maximum Efficiency

Level-hunting connectors have been made in one form or another for twenty-five or thirty years. They were required so seldom, or rather because of the expedients just discussed they were used so seldom, that they still are not as well known as they should be.

A typical modern level-hunting connector is shown in Figure 14. It can reach from one single line to a group of one hundred lines with complete efficiency. A calling subscriber dials its wipers to the directory "pilot" number (the first terminal) of a called P.B.X. subscriber. If that first line is busy and bank markings indicate the called subscriber has additional lines, the level-hunting connector hunts across them all until an idle circuit is found.

Twenty trunks in the banks of a level-hunting connector might be arranged on two levels as in Figure 13. This is not necessary, though, and twenty lines can nearly as well be grouped as in the lower part of Figure 15, the directory number then being 23.

A level-hunting connector can hunt across consecutively numbered lines no matter how many levels they occupy. The upper part of Figure 15 shows a possible grouping, in the banks of a level-hunting connector, of the lines for a subscriber with thirty-seven P.B.X. trunks, terminals 51 through 87, accessible by dialing the directory-listed pilot number 51.

Level-hunting connectors are only slightly more expensive than the more conventional single-level trunk-hunting connectors. Ordinary single-level trunk-hunting connectors with night service using bank markings per Figure 3 require, as previously

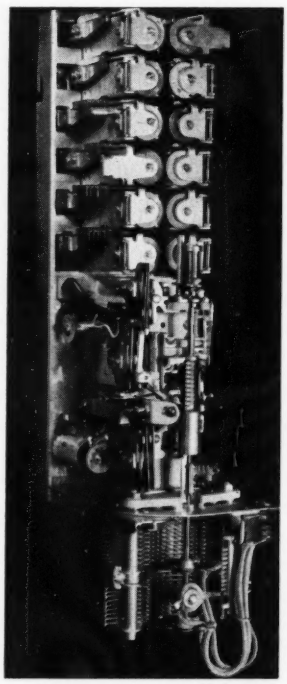


Figure 14. Typical modern level-hunting connector.

stated, eleven relays; as seen in Figure 14, ordinary level-hunting connectors require twelve relays—only *one* relay more.

Level-hunting connectors will give much better trunking efficiency than the various grading schemes discussed before. The operating company should consider whether it might not be better off in the long run to order a 100-line group of level-hunting connectors if even only one subscriber has, or in the foreseeable future will have, eleven or more P.B.X. trunks.

ERRATUM:

The switch and bank symbol shown in figure 13, page 92, has been inadvertently printed upside down.

Level-hunting connectors are spectacular in their action and it is intriguing to watch them. They use, however, only the ordinary mechanisms found on other Strowger switches such as line-finders. These include the cam springs, vertical bank and wiper, vertical interrupter springs, etc.

In Figure 16, the level-hunting connector of Figure 14 has been dialed to 51, the pilot number of the 37-line group shown in Figure 15. Vertical wiper *VW* is thus disengaged from vertical bank *VB*. Lines 51 through 63 are busy. Ground on lead *EC* of line 51 has set the connector for relay-interrupted rotary stepping, battery searching, hunting negative battery through the cut-off relay of the first idle line, 64. Rotary-interrupter relay *RI* keeps operating, closing the circuit of rotary magnet *RM*. At each busy contact *C* reached, ground prevents battery-searching relay *BS* operating. Relay *RI* re-operates, etc., and thus we step across 51, 52, 53, 54, 55, 56, 57, 58 and 59 to 50.

When the switch shaft takes the rotary step from contact 50 to the eleventh rotary position, cam springs A and B close. Relay *LH* operates, locks, through operated cam springs *B* closes the circuit of release magnet *RLS*, and, through a special resistor, magnetizes the vertical magnet just enough to engage the vertical pawl into the shaft hub (but not enough to lift the shaft nor to lift the release link). Release magnet *RLS* latches the double dog under the release link. The shaft spring rotates the wipers leftward to rotary normal. Cam springs *A* and *B* open.

When the wipers reach rotary normal, the vertical pawl, engaged by the partially operated vertical magnet, prevents the shaft from falling, and vertical wiper *VW* touches vertical bank *VB*. The vertical wiper and vertical bank short circuit the special resistor, grounding vertical magnet *VM* directly, causing it to operate fully. The vertical magnet steps the wipers up opposite the next higher level, level 6 in Figure 16, and unlatches the double dog to hold the shaft there. The vertical interrupter springs release relay *LH*. Relay *LH* releases the vertical magnet, re-connects testing ground to battery-searching relay *BS*, and, through contacts of operated relay *RI*, causes the rotary magnet to step the wipers onto bank contact 61.

Relay-interrupted stepping continues across 61, 62 and 63. When control wiper *CW* reaches line 64, relays *BS* and *CO* operate. Relay *BS* releases rotary-interrupter relay *RI*, and thus prevents further stepping. Conventional elements of the connector ring line 64 in the usual way, and conversation ensues.

Thus it is seen that level-hunting connectors are not substantially more expensive nor substantially more complicated than single-level trunk-hunting connectors. They give every caller 100 per cent coverage of *all* trunks in a group.

Using as they do the bank-marking pattern of Figure 3, level-hunting connectors give reliable (non-hunting) night service if any number subsequent to the regular daytime directory number is dialed. The test and verification connector has access to all lines in a group.

Special Connectors To Avoid "Mixed" Numbering

The connectors discussed thus far all complete a connection after only two digits have been dialed. When such connectors are reached through the same number of selectors as are three-digit type 200-line connectors, or terminal-per-line party line connectors, we have "mixed" numbering. For example, in a large exchange requiring first and second selectors, P.B.X. subscribers would have four-digit directory numbers using the basic connectors just described, while terminal-per-line party-line subscribers have five-digit directory numbers. This is not inherently bad, and has, in fact, been typical practice for many years. It has, however, become a problem with the advent and spread of nation-wide operator toll dialing and metropolitan Director networks, and may present difficulties if for these or any other reasons it becomes desirable that all directory numbers in an exchange contain the same number of digits. To meet such conditions, Automatic Electric Company has designed a number of *three-digit* trunk-hunting connectors.

Some of these three-digit connectors merely "absorb" an unused first digit, usually 1. They use 400-point banks marked per Figure 3.

To some three-digit connectors, using 400-point banks marked per Figure 3, the first digit indicates whether the connector should hunt, and the last two digits step the wipers as usual. In calling a single-line subscriber, or in calling a

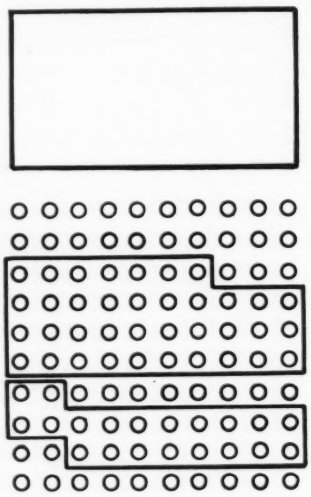


Figure 15. How twenty P.B.X. trunks (Directory Number 23) or thirty-seven P.B.X. trunks (Directory Number 51) might be grouped in the banks of a level-hunting connector. It is mechanically preferable, but not electrically necessary, that groups begin at contact number one of a level, as does the 37-line group above.

P.B.X. station at night, the first digit for the connector is 1. In the regular directory listing of a P.B.X. subscriber, the first digit for the connector is 2. Thus, if the caller dials 134 into the connector, the "1" sets the connector not to hunt, and, if terminal 34 is busy, the caller receives busy tone. This happens, when the first digit dialed into the connector is 1, regardless whether contact *EC* of terminal 34 is grounded, and terminal 35, etc., idle. If the caller dials 234 into the connector, the "2" sets the connector to hunt, and, if the terminal 34 is busy and has its contact *EC* grounded, the connector hunts until an idle line in the group is found. All P.B.X. trunk lines, even the first line in a group, can be used for night service.

Another three-digit connector, devised recently, uses no group marking in the banks, so has the advantage of using only 300-point banks. The first two digits step the wipers in the usual way. The third digit indicates the number of working lines the P.B.X. subscriber has now, plus the number of lines the telephone company has reserved for his future requirements.

In Figure 1, the P.B.X. subscriber now has five consecutive lines, 43, 44, 45, 46 and 47. If the telephone company expects he may require two more lines ultimately, 48 and 49 are held unassigned. The line and cut-off relays of 48 and 49 are disconnected, and lead *C* of each of these two lines is grounded. The last three digits of the directory number of this P.B.X. subscriber will be 437. (For the present, 435 would suffice, but the number should be 437 so the directory listing will not have to be changed each time one of the additional lines is added.)

With this arrangement, when a caller dials 437 into the connector, the first two digits take the wipers to the terminal of the first line in the group, 43. When the last digit, 7, is dialed, one dial pulse is absorbed while terminal 43 is busy-tested, and, if 43 is busy, as many of the next four dial pulses go to the rotary magnet as are required to step the wipers to an idle line. Absence of ground on lead *C* of the first idle line prevents later dial pulses from reaching the rotary magnet.

If all five working lines in the group are busy, the sixth dial pulse steps the wipers to 48, and, 48 having been made busy, the seventh dial pulse steps the wipers to 49. But 49, also, has been made busy. The caller receives busy tone.

Individual-line subscribers reached through these connectors have "1" as the final digit of their directory numbers.

With this three-digit connector, all lines in a P.B.X. trunk group can be used for night service. In the example just given for Figure 1 (and two additional reserved lines), the directory-listed daytime number is 437. The five working lines can be reached reliably (without hunting) by dialing 431, 441, 451, 461, and 471 at night.

Spread the P.B.X.'s

In a large exchange, serving many P.B.X.'s, it would be possible to put residence telephones in non-hunting connector groups only. These connectors would have light use during the day, but quite a number would be required to handle the evening traffic peak. Trunk-hunting connector groups, loaded with P.B.X.'s only, would be so busy during the day that several overflow connec-

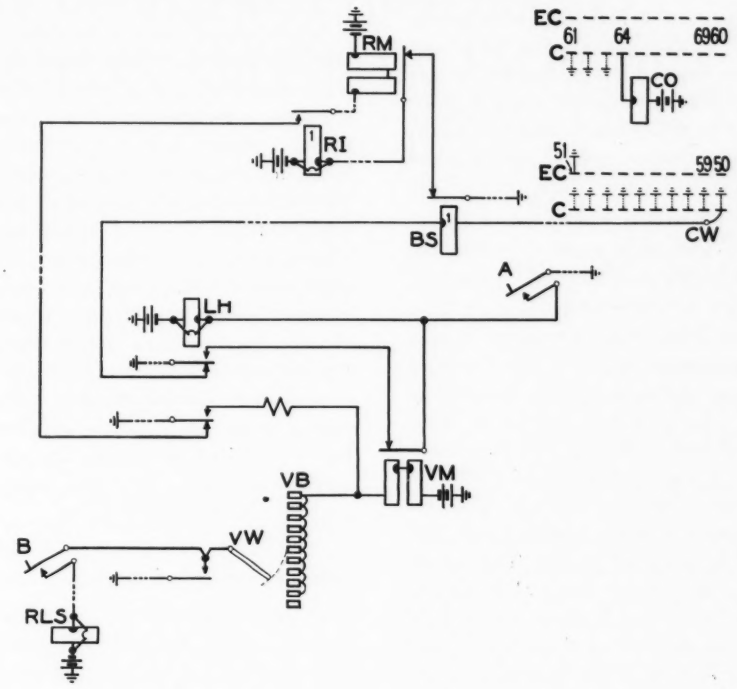


Figure 16. Trunk hunting automatic rotary and vertical stepping circuit elements of the level-hunting connector of Figure 14. In the upper right hand corner of this figure are shown levels 5 and 6 of the bank contacts of Figure 15. The wipers are shown on bank contact 50, about to take an eleventh rotary step on level 5 and then to be advanced to bank contact 61.

tor shelves would be needed; then most of this equipment would stand idle throughout the night, which would not be economical. Also, the trunking pattern from the last rank of selectors to the two classes of connectors would differ greatly.

In actual practice, it is found desirable to assign the initial working trunks of P.B.X's to only about forty per cent of the lines in a trunk-hunting connector group. After reserving further terminals for the foreseeable ultimate growth of the P.B.X. subscribers, the remaining terminals in each trunk-hunting connector group should be assigned to light users, such as residences.

This gives each trunk-hunting connector group some heavy daytime traffic and some heavy evening traffic, keeping each connector in use a greater number of the hours of the day, which is good economy. It minimizes the number of overflow connectors required, thus tending to equalize the number of connectors in each group. This makes uniform, and thus simplifies, trunking from the last rank of selectors.

For the same reasons, namely to equalize switch quantities at each rank and to have uniform trunking between ranks, in a large exchange trunk-hunting groups should be distributed approximately equally to the several thousands-groups in the office.

The Smaller Office

A small office which needs only one trunk-hunting connector group may not have even the forty P.B.X. trunks suggested as the initial maximum for the trunk-hunting connector group.

Often *all* connectors in a small exchange are three-digit connectors equipped with minor switches to select ringing current for party-line ringing. Even the trunk-hunting connectors are so equipped. Any line entering the central office can then be served by either non-hunting or trunk-hunting connectors, equally well. Trunk-hunting 100-line connectors for party lines usually use the bank-marking pattern of Figure 2.

An exchange of ultimately more than 100 but less than 200 lines often uses 200-line connectors, and is able, thereby, to avoid using selectors. The 200-line connectors of such an exchange usually must have trunk-hunting features. As Strowger switches rarely use more than 600 contacts in their banks, the 200 lines are limited to three wires each; there should be no lead *EC*. The bank-marking pattern of Figure 4 is used in 200-line connectors with trunk-hunting features. This requires that the next succeeding terminal after the last line of a P.B.X. group be vacant. The cut-off relay of this next succeeding terminal is disconnected, and 500-ohm ground is connected to lead *C* in its place. When the first or third digit dialed into the connector has set it for automatic hunting, and all lines in a P.B.X. group are busy, the 500-ohm ground on lead *C* indicates that the group has been passed over, and hunting should stop. The first or third digit dialed frequently determines whether the connector is to hunt, thus making it possible to mix individual lines, party lines, and P.B.X. trunks on one level, and to give non-hunting night service from the same terminals used for P.B.X. daytime trunk-hunting service.

The Very Small Office

In very small offices, the connector is the one and only numerical switch used. It may include a wide assortment of services, such as party-line selection, conversation timing, restricted service, selector action and switch-through on certain levels for trunks to nearby points, reverting call by directory number, etc., all in addition to P.B.X. trunk hunting. This sort of selector-connector may require that the calling party dial one or two digits into it when using it as a selector, and three or four digits when using it as a connector. Usually the first or last digit dialed determines whether the connector is to hunt. This makes it possible to mix individual lines, party lines, and P.B.X. trunks on one level, and to give the P.B.X. trunks hunting service in the daytime and non-hunting service at night, over the same terminals, by varying the first digit dialed.

Miscellaneous Services

Usually no charge is made for calls to the telephone-company business office, or emergency services such as fire, police, ambulance, etc. Trunk-hunting connectors can be equipped with normal-post springs which prevent the back-bridge relay reversing current supply to the calling station when the called party on certain levels answers. This permits the complaint and emergency calls to be made from paystations without charge.

Most other features of regular Strowger local, combination, and toll connectors are available also in trunk-hunting connectors.

THE USE OF DISTRIBUTING FRAMES IN STROWGER AUTOMATIC EXCHANGES

By N. SALVESEN

SYNOPSIS: ***Functions of distributing frames—the main distributing frame —"A" and "B" type frames—the Line I.D.F. and its applications — physical features of the Line I.D.F.— combined main frame and Line I.D.F. — trunk intermediate distributing frame—toll intermediate distributing frame—selector bank terminal frame.***

ONE of the most important considerations in the design of modern telephone offices, and particularly in automatic offices, is the provision of adequate distributing frame equipment. The functions of such facilities are: to protect line equipment by the use of heat coil and carbon type protectors; to connect subscribers' lines to the automatic switching equipment; to provide flexible means for distributing traffic; and to facilitate moves, take-outs, class-of-service changes, and the rendering of intercepting service.

The equipment which would be most generally supplied to provide these services comprises a *main distributing frame,* a *line intermediate distributing frame, trunk and toll intermediate frames, and selector bank distributing frames.* The extent to which these frames actually would be applied in a particular central office depends largely upon the size of the office and the types of frames considered best suited to meet the initial and ultimate requirements of the office.

The Main Distributing Frame

The *main distributing frame* is the junction point between the outside cable plant and the central office equipment. At this frame, by means of jumper wire, connections are made between subscribers' lines and their associated line and terminal equipments.

In general, the main frame consists of columns of ironwork spaced eight inches apart. On one side of these columns, known as the vertical side, conventional heat coil and carbon type protectors are mounted, while on the other side, known as the horizontal side, suitable terminal blocks are mounted. Standard frames are available in several heights, designated by the number of protector pairs per column, such as 100, 150, 200, or 300 pairs, to meet the requirements of central offices of various sizes. Similarly, protector blocks are available with the heat coil and carbon type protectors mounted on either ⅜-inch or ½-inch centers. The ½-inch type is generally used with low type frames and in smaller offices, while the ⅜-inch type is preferred in larger offices since it is particularly well suited for use with high type frames.

There are two general types of main distributing frames; namely, the "A" type and the "B" type. The *"A" type frame* has the outside cable pairs terminated on terminal blocks mounted on the horizontal side of the frame, while the line cables from the switching equipment are connected to protectors mounted on the vertical (switchboard) side of the frame.

The arrangement on the *"B" type frame* is exactly reversed; that is, the outside cable pairs are terminated on protectors on the vertical side while the cables from the switching equipment are terminated on terminal strips on the horizontal (switchboard) side. While somewhat more costly, the "B" type frame has the advantage that the protective equipment is connected directly to the outside cables, thus effecting protection of the jumper wiring, in addition to protecting the central office equipment.

In exchanges where no line intermediate distributing frame is used, the connector terminals are cabled to the switchboard side of the main frame, which may be of either the "A" or "B" type. The connector terminals and the line finder terminals are permanently connected together by direct cabling between their respective shelves.

The Line Intermediate Distributing Frame

The purpose of the *line intermediate distributing frame* (generally referred to as the Line I.D.F.) is to provide facilities whereby the connector terminals may be cross-connected, as desired, to the line finder terminals (line equipments), and extended via tie cables to the main frame for cross-connecting to the subscribers' lines. The advantages of the flexibility effected by line finder terminal and connector terminal cross-connections are many and far reaching; under actual operating conditions they will be found to offer certain desirable values, from the viewpoints both of equipment flexibility as well as outside plant usage.

In central offices wherein the party lines are operated on a terminal-per-station basis, a Line I.D.F. is always required. In central offices wherein the party lines are operated on a terminal-per-line basis, the need for a Line I.D.F. is not quite so pronounced as in the terminal-per-station type, but will nevertheless be found to be highly desirable from traffic and other viewpoints. The Line I.D.F. may either be a separate frame or be combined with the main frame. Some of the principal advantages of the Line I.D.F. will be discussed more fully in the subsequent paragraphs.

(a) *Distribution of Originating Traffic*—Since the fundamental purpose of the Line I.D.F. is to effect dissociation of line finder terminals from connector terminals, it follows that by its use any line finder terminal may be connected to any connector terminal, thus making it easy to provide and maintain an even load distribution over all of the working line finder groups.

Even though all possible precautions have been taken in the assignment of connector terminals to the various line finder groups, it invariably happens that some line finder groups will be overloaded while others will be underloaded. Redistribution of some of these assignments, through changes in jumpers at the Line I.D.F., makes it possible to effect an even distribution of originating traffic without the necessity of changing subscribers' directory numbers.

Without a Line I.D.F., overloaded traffic conditions can be corrected only by installation of additional line finders and associated first selectors,

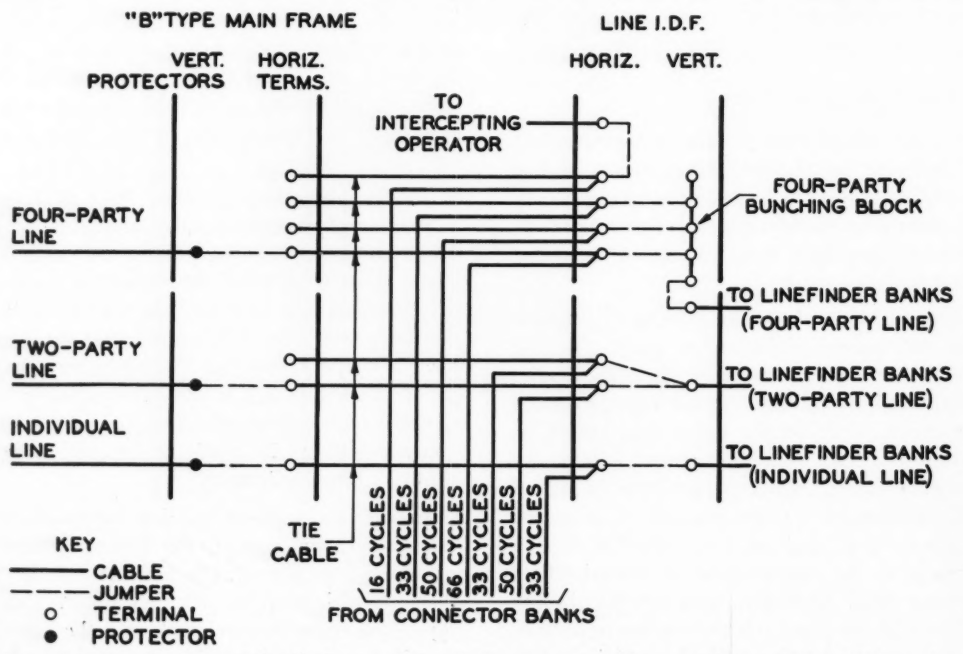


Figure 1. Schematic diagram of main frame and Line I.D.F. showing party line grouping and intercepting service.

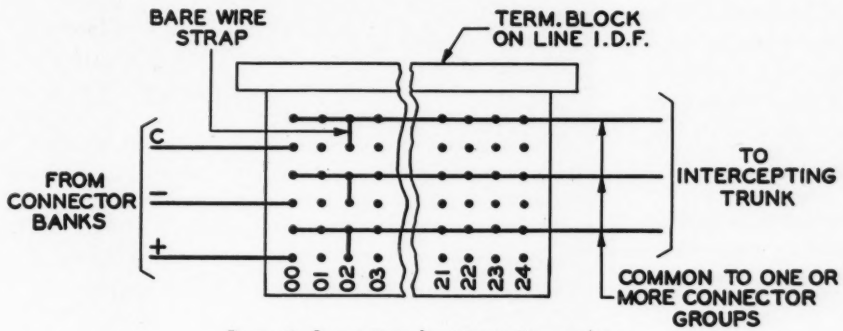


Figure 2. Connections for intercepting service.

or by a regrouping of the line finders on the various shelves, if line finders are available in sufficient number. This could in some line finder groups result in line finder requirements which would exceed the capacity of the line finder shelf. The only remedy for such a condition would be to reduce the number of working lines in the affected line finder groups to a point where the available line finders could carry the load. Obviously, this is not a desirable arrangement since it reduces the availability of the line equipments, and also requires changes in subscribers' directorv numbers.

(b) *Efficient Use of Outside Cable Plant*—In the operation of an automatic telephone plant, where party line service is rendered, it sooner or later develops that, due to moves, take-outs, changes in classes of service, and similar reasons, the "station fill" on party lines becomes reduced. Many two-party lines will have only one station connected per line, and four-party lines will often have only two or three stations per line. Such conditions impair the efficient use of the outside cable plant by tying up cable pairs which otherwise could accommodate additional subscriber stations.

In central offices operating on a terminal-per-station basis, the use of the Line I.D.F. makes it possible, by merely changing jumpers, to transfer and combine stations on party lines so as to effect the desired station fill of the lines, without the necessity of changing subscribers' directory numbers.

The combining of stations on party lines, in order to effect a full saturation of the lines, may, of course, also be done in central offices operating on a terminal-per-line basis. However, in this type of office it will be necessary to change some of the subscribers' directory numbers and to place the vacated numbers on intercepting.

(c) *Increasing Usage of Subscribers' Line Circuits*—In central offices where no Line I.D.F. is provided, the line finder terminals are cabled directly to the connector terminals. Therefore, the number of line finder terminals and the number of connector terminals must necessarily be the same. Since in all connector groups there always will be a number of unassigned terminals, as well as a number of terminals on intercepting, it may readily be seen that the line equipments (line finder terminals) associated with these vacant connector terminals will be idle and in the case of intercepted terminals may, perhaps, remain idle for some time.

When a Line I.D.F. is used it becomes possible to dissociate the line finder terminals from the connector terminals and thereby effect full usage of the line equipments. For example, in the case of discontinued service (take-outs), the line equipments may immediately be re-used while the connector terminals would have to be placed on intercepting for a period of time. Many operating companies take advantage of this unequal ratio of working lines to working connector terminals by providing a greater number of connector terminals than line finder terminals thereby using the line circuits to their fullest extent.

(d) *Party Line Grouping and Intercepting Service* — In central offices operating on a terminal-per-station basis, the Line I.D.F. provides easy means for grouping party line stations, changing classes of service, moving party line stations from one line to another without changing their directory numbers, and intercepting calls to stations on which service has been discontinued.

Figure 1 shows diagrammatically how connector terminals and line finder terminals are connected together, how party lines are formed, and how, by merely changing jumpers, various changes in service may readily be made.

Four-party lines are grouped by means of *bunching blocks,* as shown in Figure 1. Four sets of terminals, one set from each of four connector groups, each group having a different ringing frequency, are "bunched" together and connected to one line equipment (line finder terminal), thus forming a four-party line.

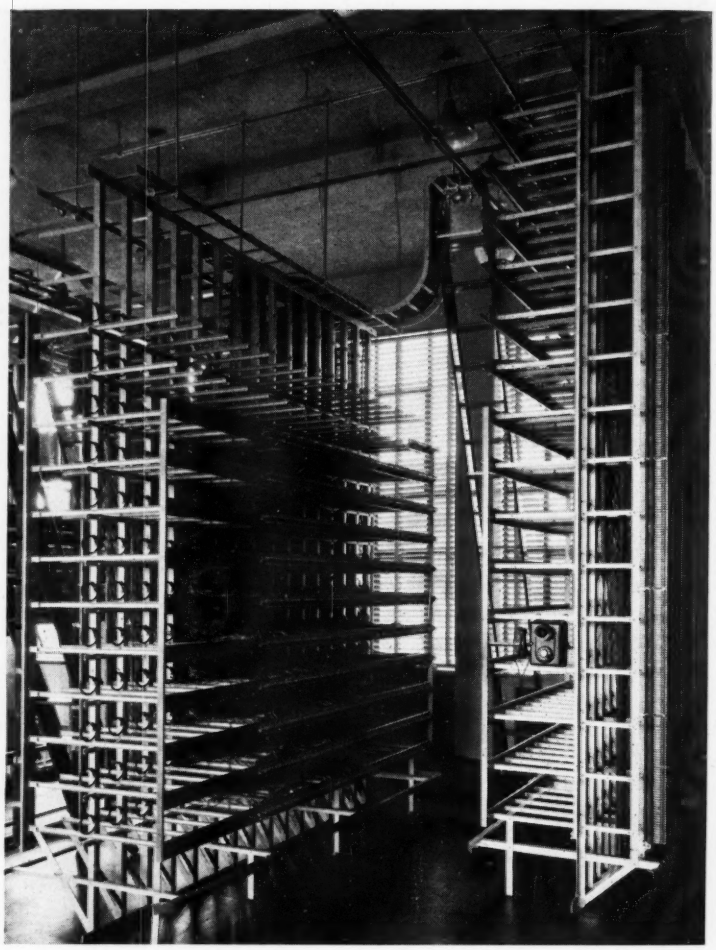


Figure 3. An installation of Line I.D.F. at the left and "B" type main frame at the right.

In the example shown in Figure 1, the 16-cycle station has had its service discontinued, and has been placed on intercepting. This is accomplished by merely strapping the connector terminals to the intercepting trunk terminals as shown for line 02 in Figure 2. In a similar manner any station may, as required, be placed on intercepting. If an individual line, or an entire party line, is placed on intercepting, the jumper to the line finder terminal must also be disconnected. The released line finder terminal may immediately be assigned to another subscriber's line.

A two-party line, as shown in Figure 1, is formed by jumpering two connector terminals direct to the terminal of the line equipment. If bridged harmonic ringing is used, the two connector terminals are one from each of two connector groups, each group having a different ringing frequency. If divided ringing over each side of the line to ground is used, the same ringing frequency is used for both connector terminals. With bridged ringing the jumpers to the line equipment are run "straight", while with divided ringing the line jumpers are reversed.

Individual lines are connected straight through to their respective connector and line finder terminals as shown in Figure 1.

Construction and Cabling of the Line I.D.F.

The construction of the Line I.D.F. is quite similar to that of the main frame, except that terminal blocks are provided on the vertical side in place of protectors.

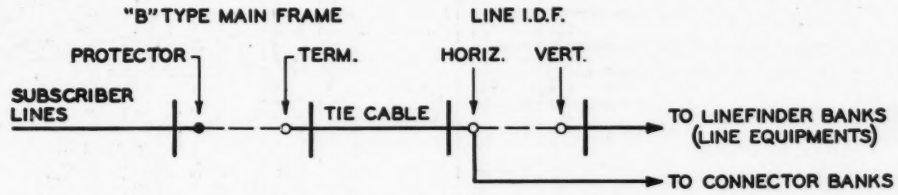


Figure 4. Connector banks extended to the main frame.

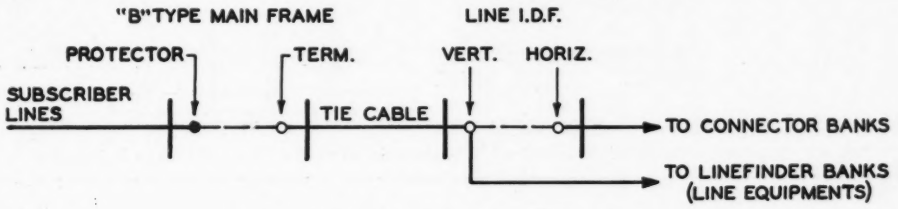


Figure 5. Line finder banks extended to the main frame.

A typical Main Frame and Line I.D.F. arrangement is shown in Figure 3. As in this example, the preferred method of installing the Line I.D.F. is to place it parallel to the Main Frame.

The cables from the connector banks to the Line I.D.F. are terminated on the horizontal side of the frame and the cables from the line finder banks are terminated on the vertical side. In central offices engineered on the basis of terminal-per-station operation, the "bunching" blocks for the four-party lines are, generally, also mounted on the vertical side.

There are two methods in use for cabling from the Line I.D.F. to the main frame. These two methods are shown diagrammatically in Figure 4 and Figure 5. In the method shown in Figure 4 the connector terminals are cabled to the main frame, while in the method shown in Figure 5

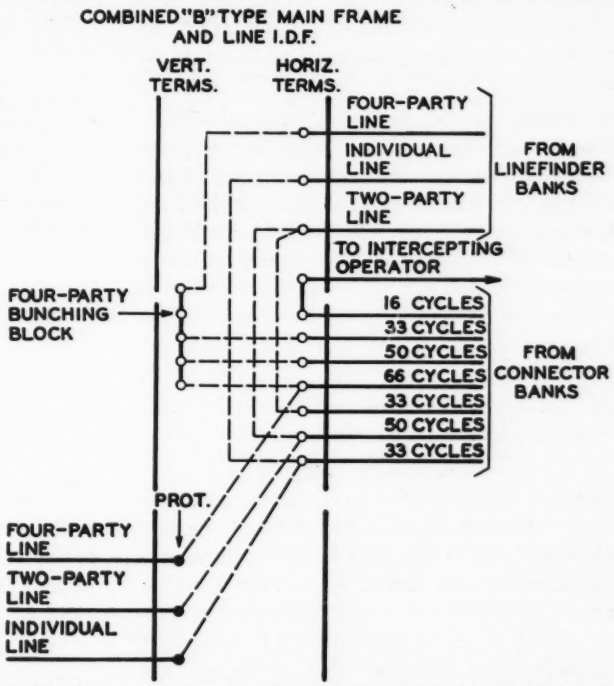


Figure 6. Schematic diagram of a combined "B" type main frame and Line I.D.F.

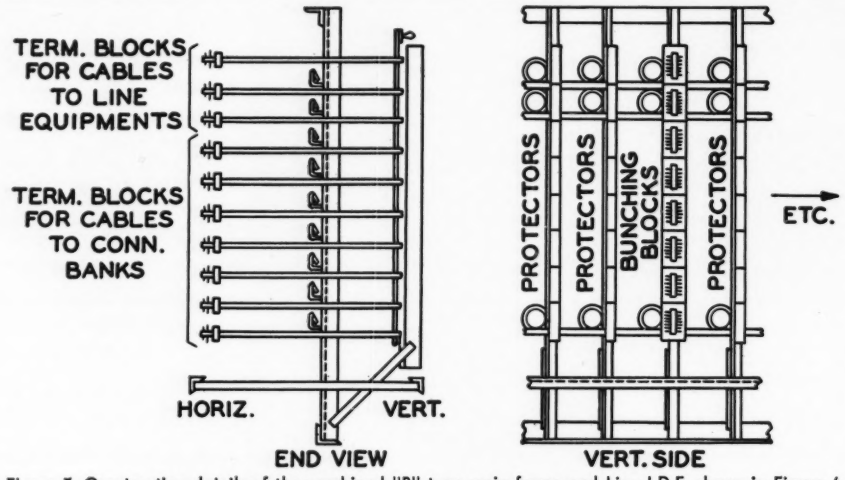


Figure 7. Construction details of the combined "B" type main frame and Line I.D.F. shown in Figure 6.

the line finder terminals are cabled to the main frame.

In central offices engineered on a terminal-per-line basis, the plan shown in Figure 4 is practically always used since in this type of office the number of connector terminals is generally the same as, or only slightly more than, the number of line finder terminals.

In central offices engineered on a terminal-per-station basis, wherein the number of connector terminals is always considerably in excess of the number of line finder terminals, there is the item of cost to be considered. For example, in an exchange of 3000 lines and 6000 connector terminals it will be seen that the plan shown in Figure 4 would require 6000 cable pairs between the Line I.D.F. and the main frame, while the plan shown in Figure 5 would only require 3000 cable pairs.

The arrangement shown in Figure 4 has two advantages which may be worth considering:

(1) When for the purpose of traffic adjustment jumpers are changed between connector terminals and line finder terminals, it is necessary to change the jumpers only at the Line I.D.F. With the arrangement shown in Figure 5 it will be seen that since the subscribers' lines are not connected directly to the connector banks it will, with that arrangement, be necessary also to change the jumpers at the main frame.

(2) The arrangement shown in Figure 4 has the connector terminals (subscribers' line numbers or station numbers) connected directly to the main frame and the terminal blocks on the frame are correspondingly numbered. The arrangement shown in Figure 5 has the line finder terminals connected to the main frame, and since any line finder terminal may be connected to any connector terminal, the main frame numbering will, therefore, have no direct association with the subscribers' line or station numbers.

There is however, in the arrangement shown in Figure 4, a slight disadvantage which perhaps can best be understood by reference to Figure 1. If, in a central office operating on a terminal-per-station plan, the particular two-party or four-party terminal to which the jumper on the main frame is connected should either be moved to another line, or be intercepted, it will be necessary to connect the jumper to one of the other terminals of the same line.

The Combined Main Frame and Line I.D.F.

In medium size central offices where full Line I.D.F. facilities are wanted, but where a separate Line I.D.F. is not desired, a combined *Main Frame and Line I.D.F.* may be used.

The combined main frame and Line I.D.F. combines in one framework the main frame protectors and the Line I.D.F. terminal blocks. Figure 6 shows diagrammatically how the same facilities

provided with the separate main frame and Line I.D.F. shown in Figure 1 may be incorporated in the combined frame. Figure 7 shows the general construction of the frame. The protectors and four-party bunching blocks are mounted on the vertical (outside cable) side of the frame, while the terminal blocks for the cables to the line finder banks and connector banks are mounted on the horizontal (switchboard) side. The use of the combined frame should be limited to central offices of not more than approximately 2500 lines, as jumper congestion is likely to develop if such a frame is installed in larger offices.

The combined main frame and Line I.D.F. is primarily applicable for use as a "B" type frame. When used as an "A" type frame, it effects very little, if any, saving in either cost or floor space over the separate Line I.D.F. arrangement.

The Trunk Intermediate Distributing Frame

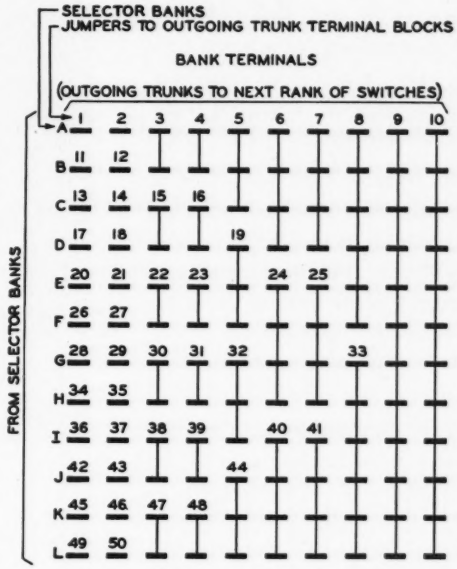
The function of the *trunk intermediate distributing frame* in an automatic central office is to provide means for cross-connecting line finders to first selectors, and also, as in the case of offices in multi-office areas, to cross-connect the outgoing trunks from selector levels to outgoing secondary lineswitches and repeaters.

The purpose of cross-connecting line finders to first selectors is to obtain improved distribution of traffic by connecting the line finders on each shelf to first selectors distributed over the various first selector shelves. The effect of this distribution is to obtain, on each succeeding call, a different outgoing trunk from the selector level.

The trunk intermediate distributing frame may be either a separate frame or part of the Line I.D.F. or, in the case of small central offices, part of the main frame.

The Toll Intermediate Distributing Frame

In central offices having large toll boards it is generally desirable to have a separate *toll intermediate distributing frame*. The purpose of this frame is to provide flexible means for connecting and associating the various toll lines with their respective trunk circuits, coils, composite equipment, etc. and for extending the various circuit leads to the face equipment in the toll board. In smaller offices this frame is often combined with either the main frame or the trunk intermediate distributing frame.


SELECTOR BANKS
JUMPERS TO OUTGOING TRUNK TERMINAL BLOCKS
BANK TERMINALS
(OUTGOING TRUNKS TO NEXT RANK OF SWITCHES)
FROM SELECTOR BANKS
A 1 2 3 4 5 6 7 8 9 10
B 11 12
C 13 14 15 16
D 17 18 19
E 20 21 22 23 24 25
F 26 27
G 28 29 30 31 32 33
H 34 35
I 36 37 38 39 40 41
J 42 43 44
K 45 46 47 48
L 49 50
Figure 8. Typical selector level grading.

The Selector Bank Terminal Frame

When a Strowger selector rotates over a group of bank contacts, the first few contacts of the group will carry the greater portion of the offered traffic. By employing an arrangement known as "grading", wherein individual contacts are provided for one or two first choice trunks and common contact groups of various sizes are provided for the remaining trunks, the efficiency of the low traffic carrying last choice trunks will be materially increased. Such an arrangement is shown in Figure 8, which illustrates a typical grading of a selector level wherein the bank contacts from a group of 120 selectors are progressively graded to provide access to a group of 50 outgoing trunks.

It is generally recognized that grading increases the traffic carrying capacity of a trunk group anywhere from 15% to 20% over that of smaller groups of 10 trunks each. The percentage increase is, of course, dependent upon the size of the trunk group and the density of the traffic carried by the group. This increased efficiency reflects itself in the saving of switches in successive ranks of

selectors or connectors, as the case may be, since fewer switches will be required for a given traffic when grading is employed, than when small, ungraded trunk groups are used.

In order to take advantage of the increased efficiency effected by grading, as well as to provide flexible means for regrouping and changing trunk groups, the *selector bank terminal frame,* or *distributing terminal assembly* as it is most frequently called, is used.

The distributing terminal assembly is an integral part of the selector board, and is located in the middle of the board, between the two bays of selector switches, as illustrated in Figure 9. The terminals from each set of 10 banks are wired to special terminal strips, each strip consisting of 10 horizontally mounted blocks, one block for each of the 10 levels. The terminal strips are mounted one above the other in the terminal assembly, so that the corresponding terminals of each level are directly above one another, thus permitting grading and grouping of the terminals to be done by means of short vertical strap wires.

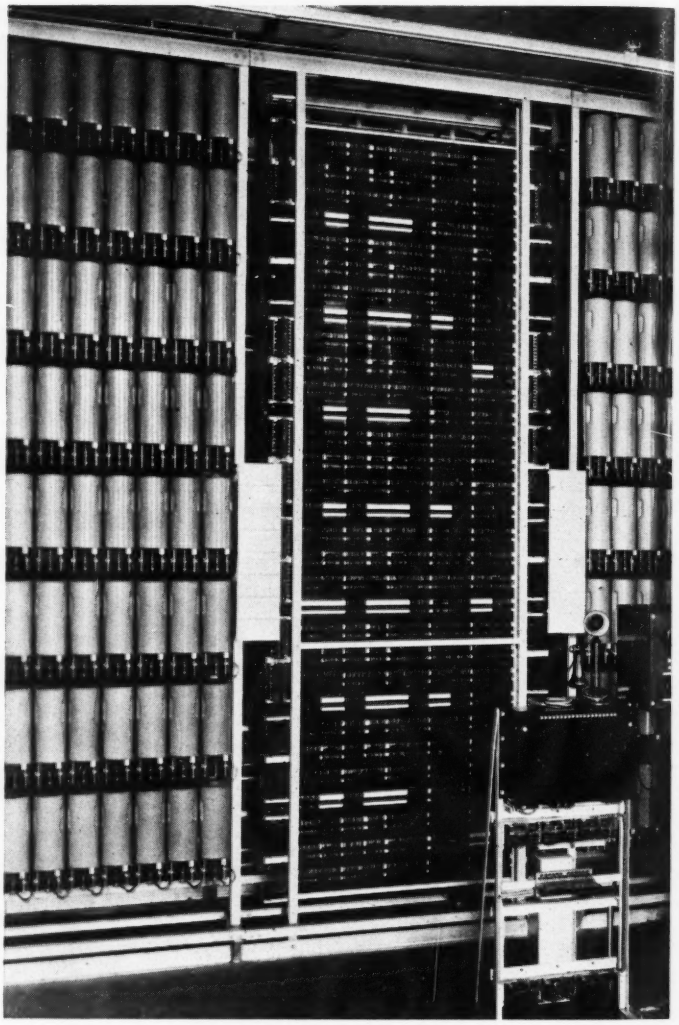


Figure 9. A distributing terminal assembly.

The outgoing trunk cables to the next rank of switches are terminated on blocks mounted vertically on each side of the distributing terminal assembly. Connections between the outgoing trunk cables and the bank terminals are made by means of jumper wire. Levels 1 to 5 are jumpered to the terminal blocks on the left side of the frame and levels 6 to 0 are jumpered to terminal blocks on the right side of the frame. Thus, changes in grading and trunk grouping, as required to meet varying traffic conditions, may easily and conveniently be made by simply changing and re-arranging the vertical strapping of the bank terminals and changing the jumpers to the outgoing trunk terminals blocks.

THE TYPE 47 VOICE FREQUENCY REPEATER

By H. C. TALCOTT

SYNOPSIS: *Field of application for V.F. Repeaters—two-wire repeaters —balancing networks—four-wire repeaters — Type 47 Repeater — unit design — hybrid circuits — amplifier unit—jack panel and power supply unit — line terminating unit — four-wire line unit—signaling.*

THE Type 47 Voice Frequency Repeater has been designed to provide a flexible means of improving voice transmission on long distance telephone circuits operated by telephone companies, railroads, pipe line companies, and other organizations using wire communication facilities under widely varying field conditions. An important feature of the system is its use of a unit type arrangement which permits meeting a wide variety of operating conditions by use of a few basic units in appropriate combinations.

General Considerations

On all types of lines, the voice-frequency signal suffers a loss which is directly proportional to the length of the line. Therefore, if no means were provided to amplify the signal, most of today's long distance telephone calls would be impossible. Under favorable conditions, present day cable will permit satisfactory transmission over distances up to 100 miles. With open wire, transmission over distances up to 300 miles is possible. These facilities alone would certainly limit the service provided to telephone subscribers. However, these limitations can be overcome in two ways. Larger size wire can be used to reduce the losses; but for lines several hundred miles long the cost and bulk make this method impractical. The other way is to boost the power at one or more points along the line to compensate for the losses suffered. This is the method commonly employed in the industry, telephone repeaters being used for this purpose.

Consider a toll telephone line consisting of a 16-gage loaded cable 1,000 miles long, all of which is a fairly representative circuit. The transmission loss is such that only 0.1^{19} of the power sent at one end would be received at the other end. One repeater capable of boosting the input so that the energy received would be equal to the energy sent is impossible. Nor would two or three repeaters be sufficient. However, by placing repeaters at intervals of about 40 miles along the line, the signal can be "boosted", or amplified, in steps of practical size. Larger wires will permit wider spacing of repeaters, but it has been found more practical to use the smaller gage, less expensive cable, with more repeaters, even over comparatively short distances. In practice repeaters are placed at the terminals of a toll circuit as well as at intermediate points.

Vacuum tubes are universally used as amplifying elements of the repeaters. Since the vacuum tube is a one-way device, it can operate in only one direction of transmission. For two-way transmission, therefore, it is necessary to use two vacuum tube amplifiers in either a four-wire circuit—with each pair of wires carrying the conversation in one direction—or in a two-wire circuit which is converted into a four-wire circuit at each repeating point where the voice signals are amplified independently in each direction.

Two-Wire Repeaters

A two-wire repeater generally involves the following:

1. The use of one-way amplifiers designed to provide the necessary gain, or "boost", in order to overcome the toll line losses.

2. The use of special circuits, called hybrids, for converting two-wire circuits into four-wire circuits.

3. The use of proper balancing networks for closely approximating the impedance of the line and associated apparatus.

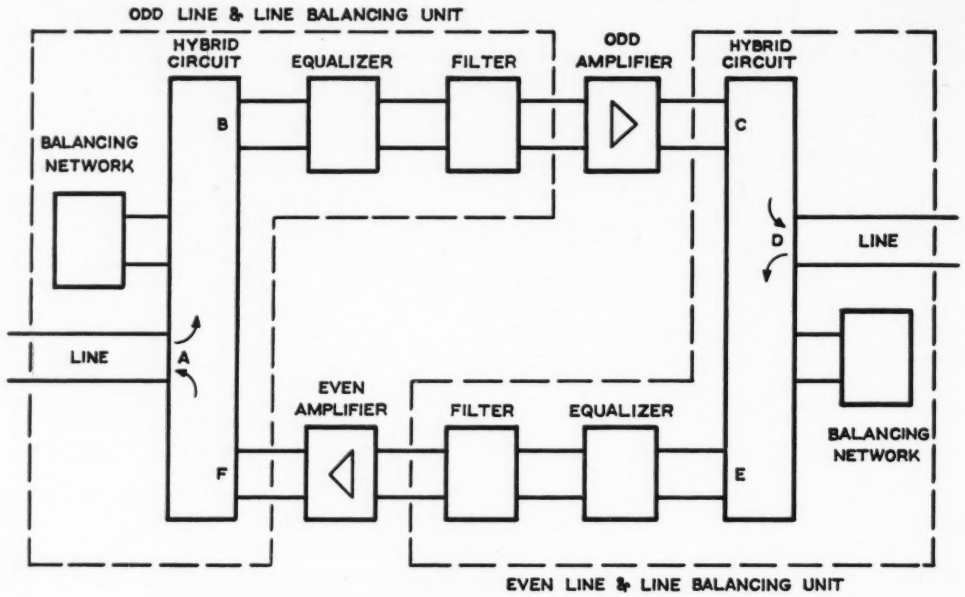


Figure 1. Two-wire intermediate repeater showing Type 47 unit arrangement.

4. The use of filters for eliminating any energy outside the frequency range necessary for good quality voice transmission.

5. The use of miscellaneous apparatus and circuit features for adapting the telephone repeater to standard operating practices. Power, testing, signaling, equalization, regulation, and maintenance considerations are included here.

The four-wire repeater, providing an independent circuit for each direction of voice transmission, is not as complex as the two-wire repeater, mainly because no hybrid or balancing circuits are necessary. All other features of the two-wire system are provided.

The two-wire intermediate repeater, as shown in the block diagram in Figure 1, is inserted in the toll line at suitable points between toll offices. The designations "odd" and "even" are used to distinguish between two identical groups of equipment associated with the same toll transmission line, but used for carrying voice-frequency signals in opposite directions. The terms "east" and "west" are sometimes used, "west" being the same as "odd" and "east" being the same as "even". It is common practice to install "odd" equipment for carrying signals coming from the west or south, and "even" equipment for carrying signals coming from the east or north.

A signal traveling from left to right (*ABCD* in Figure 1) enters the odd hybrid circuit at *A* and no energy is absorbed in the balancing network because of a balanced condition in the hybrid circuit. The energy at *F* is dissipated at the output of the even amplifier because an amplifier is a one-way device. The signal appearing at *B* passes through the equalizer, filter, and then the amplifier, where it is boosted by a controlled amount. The even hybrid circuit receives the amplified signal at *C*, and sends one-half of the energy out over the line at *D*. The other half is absorbed in the balancing network. None of the signal appears at *E* because of the balanced condition between the line and the balancing network. The signal passing from right to left follows the path *DEFA*, and can be traced in the same manner.

In the preceding discussion, ideal conditions have been assumed. However, in practice numerous problems are presented. Obtaining a high degree of balance between the line and balancing

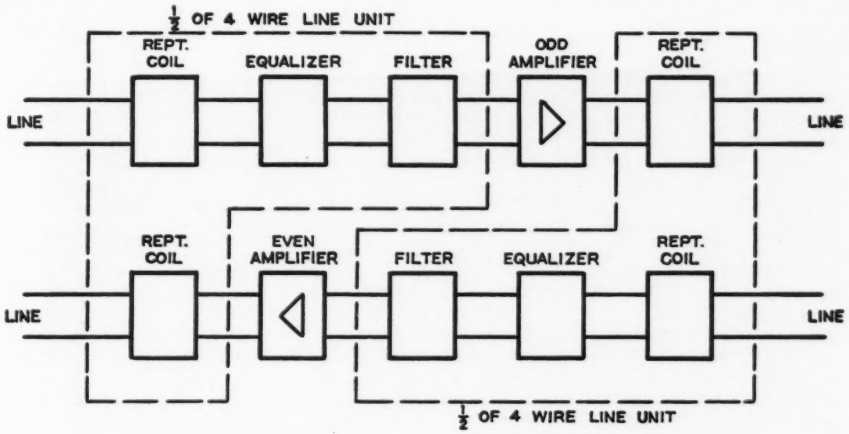


Figure 2. Four-wire intermediate repeater showing Type 47 unit arrangement.

network is of utmost importance. The results of poor balance severely impair the quality of voice transmission, and may make the whole toll circuit inoperative. This fact becomes evident upon analysis of Figure 1, assuming an unbalanced condition between the lines and their respective balancing networks. Consider the amplified signal at *C*. Because of the unbalanced condition, an appreciable part of this signal appears at *E*, is amplified again by the even amplifier and interferes with the incoming voice signal at *A*. Part of this interfering signal also appears at *B*. Reaching the odd amplifier, it is amplified still more and is applied to the even hybrid circuit at *C*. Now this amplified stray signal has travelled completely around the equipment circuit. Distortion of the transmitted signal occurs, and if the hybrid unbalance is sufficient the circulatory signal will increase and finally build up to a point where a sustained tone will result. This condition is commonly called "singing". The frequency is usually high, and since it is sent out over the line in both directions, conversation becomes impossible.

In a two-wire repeater, then, in order to realize substantial gain, the line and network must be closely balanced. Adjustable networks are provided for balancing any line, but sometimes fixed networks called prevision networks may be used when the line has stable impedance characteristics. A balanced line and network condition is also dependent upon the balance of certain windings of each hybrid coil. By careful design a high degree of balance between these windings is provided. Equally close balancing of the networks can then be achieved, all of which permits the use of reasonably high gain two-wire repeaters.

The capacitive characteristics of toll lines cause more attenuation at higher frequencies than at lower frequencies. Under this condition, speech sounds muffled and is difficult to understand. Loading coils are commonly used for decreasing this form of distortion in cable circuits and the coils are added to the cable pairs at regular intervals. With open wire, wider spacing of conductors can be used. However, complete compensation over the entire voice frequency range is not always possible by this means, and so on most toll circuits additional compensation is desirable. Equalizers are provided for this purpose. They are usually adjustable resistance-capacitance networks designed to provide attenuation-frequency characteristics which, when combined with those of the line, result in uniform characteristics.

The human ear will respond to sound at frequencies ranging from 15 to 15,000 cycles per second. However, voice frequencies do not cover such a wide range. Furthermore, it is relatively difficult and costly to design telephone apparatus which will provide satisfactory operation over this range of frequencies. Therefore, most telephone equipment is designed to function over only a relatively narrow band in the audible range. A

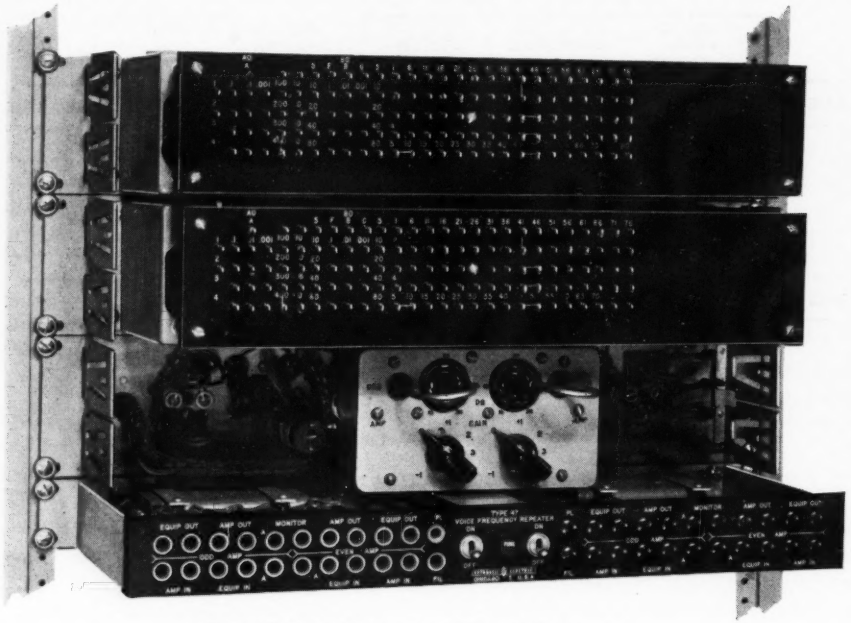


Figure 3. Type 47 two-wire intermediate repeater.

range of 300 to 3,000 cps. has been found adequate to provide intelligible speech, and many equipment design problems are simplified by the use of this narrow band. Above 3,000 cps., it is difficult to balance and to equalize circuits, and crosstalk problems become more serious. A filter made up of coils and condensers is provided to eliminate these unwanted high frequencies. Frequencies below 300 cps. are not so troublesome, and are controlled by an equalizer.

A two-wire terminal repeater is used at the end of a toll line where the circuit terminates in a switchboard. Since terminal sections of a toll circuit are usually shorter than intermediate sections, only moderate gain is required. Correspondingly smaller amounts of equalization are needed. Switchboard drops have 600 ohms impedance, and therefore several economic compromises can be made in the design of terminal repeaters. The incoming equipment on the line side is the same as one-half of an intermediate repeater. On the outgoing or switchboard side, a resistance hybrid is used in place of the coil hybrid. A single, fixed

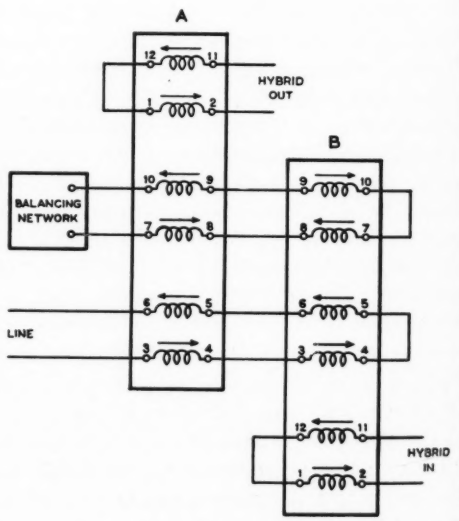


Figure 4. Repeating coil hybrid.

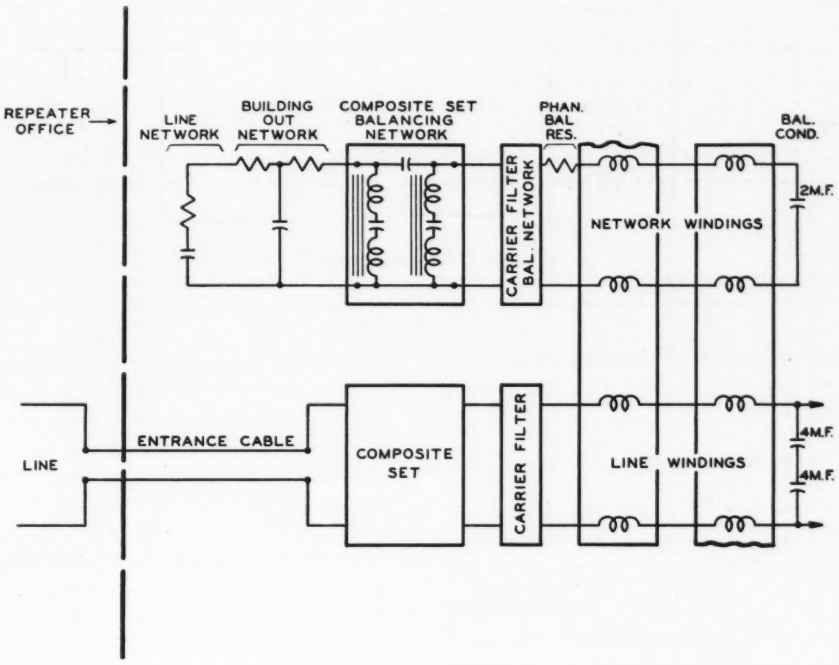


Figure 5. Balancing network.

type of network balances the switchboard drop, and the filter and equalizers are omitted entirely. This arrangement provides an economical means for converting the two uni-directional circuits of either two-wire or four-wire repeaters, into switchboard circuits.

In addition to the transmission of voice frequency signals, it is necessary to accommodate standard telephone and telegraph signals, including 20-cycle, 135-cycle, and 1,000-cycle signals, and dial pulses. Signals at 3.5 cycles, used in railroad dispatching, may also be encountered.

Four-Wire Repeaters

Four-wire repeaters, employing a separate pair of wires for each direction of transmission, do not introduce balancing problems. Higher gain is possible, which permits wider spacing of repeaters along a toll line. Two identical groups of components are provided—one for each direction of transmission.

The Type 47 Repeater

The Type 47 Voice Frequency Repeater includes equipment for two-wire and four-wire, intermediate and terminal repeater requirements. Since some components are common to various applications, unit design is employed, which facilitates manufacture, installation, and maintenance. The broken lines in Figures 1 and 2 show this arrangement. The apparatus for each unit is designed for standard 19-inch rack mounting. A terminal block is provided at the rear of each unit for installation cabling. Like units can be grouped together, as is usually the case for large installations, or the units comprising one repeater can be mounted together. A two-wire intermediate repeater requires 12¼ inches of vertical rack space, a two-wire terminal repeater requires 10½ inches, and a four-wire intermediate repeater requires 8¾ inches. The two-wire intermediate repeater shown in Figure 3 is typical. Variable components are terminated on front sub-panels and adjustments can be made by strapping solder-

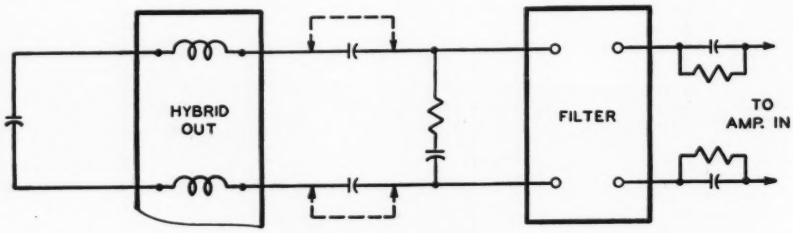


Figure 6. Two-wire equalizer.

type terminals. Slip-on type dust covers are provided for all units except the Jack Panel and Power Supply Unit.

Line and Line Balancing Unit

Each line and line balancing unit includes a hybrid coil circuit, line balancing network, equalizers, filter, and cut-out relay, all of which are mounted on a 3½ inch panel.

The hybrid circuit is made up of two precision wound repeating coils connected as shown in Figure 4. The arrows show relative polarity of windings. Each coil has six windings in order to provide connections for phantom, equalization, and signaling arrangements. Four of these windings (3-4, 5-6, 7-8, 9-10) are electrostatically shielded from the others and are wound with quadruplex wire—four strands bound together—in order to make them as nearly identical as possible. They are associated with either the line or the balancing network and are referred to as *line windings* or *network windings*. The other windings are connected to the amplifier, and are designated *hybrid out*, and *hybrid in*. Four coils having different ratios between the *hybrid out* (or *hybrid in* windings) and the line windings are available in order to permit matching any type of toll circuit to the 600-ohm impedance of the amplifier. The coils are of the low impedance, non-ring-through type, so as to pass a 135-cycle signal, but to reject a 20-cycle signal. In addition to a small coil loss, the signal suffers a theoretical 50 percent, or 3-decibel power loss in passing through the coils in either direction. Current received from the line flows through the line windings of both coils and induces equal voltages in the network windings. Assuming that the impedance of the balancing network is the same as that of the line, no current flows in the network windings because of the reversed connections between coils. Equal voltages are induced in the *hybrid in* and *hybrid out* windings, thus dividing the power equally between these windings. Current received from the even amplifier flows in the *hybrid in* windings, inducing equal voltages in the line and network windings of the *B* coil. The resulting currents also flow in the corresponding windings of the *A* coil. The line and network windings produce magnetic fields, equal in magnitude, in the *A* coil. Because of the reversed connections of the network windings between coils, these fields are opposite in effect, and therefore no voltage is induced in the *hybrid out* windings. The power from the amplifier then divides equally between the line and the balancing network.

The balancing network contains numerous values of resistance, capacitance, and inductance. Connections to terminals on a front panel make it possible to adjust the network so as to match the characteristics of various toll facilities. Figure 5 illustrates the network, which is divided into several functional parts each of which is specifically designed to balance the line, entrance cable, composite set, and any resistances and capacitances used in phantom and signaling arrangements. The line balancing network configuration is a series resistance-capacitance combination. When precision type line balancing networks are used, they can be connected at the rear terminal block. A T-section having series resistance and shunt capacitance provides a building out network for balancing any entrance cable. Heavy duty composite sets of Automatic Electric or Western Electric manufacture can be balanced by repeat-

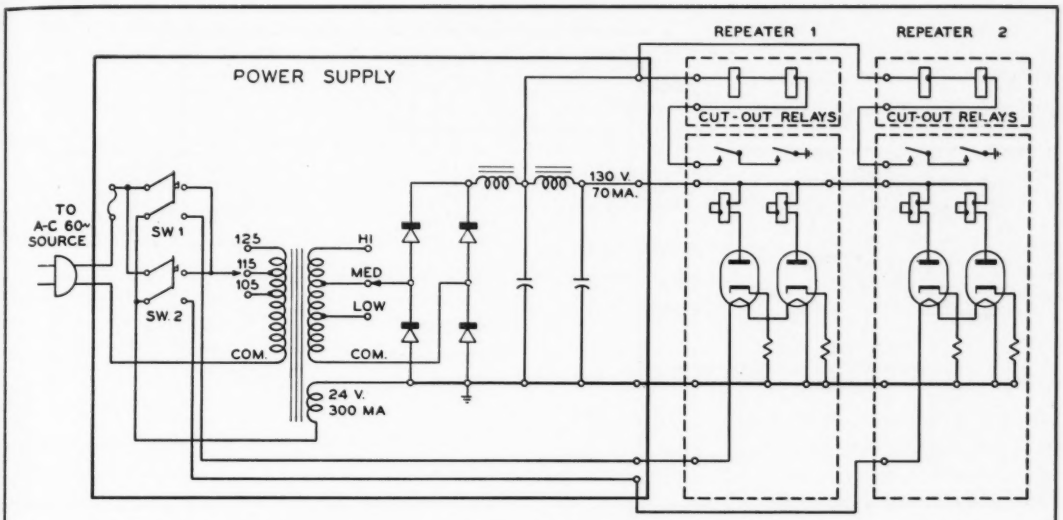


Figure 7. Power supply and alarm circuit.

ing coil type inductances. In addition, several condensers and resistors are supplied for balancing those used in the various signaling and phantom arrangements.

In the Type 47 Repeater, equalizers are provided on both sides of the filter, as shown in Figure 6. In addition, due to a characteristic of the filter, there is an interaction between the filter and equalizers which helps to provide a wide variety of shapes in the frequency characteristic. In most cases the equalizer inserted between the hybrid and filter is sufficient. However, for larger amounts of equalization, parallel combinations of resistors and condensers can be connected in series between the filter and amplifier. The condensers resonate with the series inductances in the output of the filter, and the resistors modify this effect. The equalizer at the hybrid output can be used to limit clicks, thumps, and other forms of low frequency interference common to various signaling arrangements.

The filter is a low pass, balanced, composite type, made up of a K-section input and an M-derived end section output, and is designed to work into 600 ohms. It introduces practically no loss in the pass band and cuts off at the rate of 10 db per 500 cycles. The frequency response can be made to rise just before the cut-off point by terminating the input with an impedance less than 600 ohms. This factor helps to simplify equalization and in many cases the equalizer consists of only a shunt-connected resistor. Filters having three different cut-off frequencies are provided, and their -10 db points are 3500, 2850, and 2450 cps. The 3500-cycle filter is used with most open wire circuits and with some cable circuits having cut-off points above 3500 cps. When the cut-off frequency is lower, or when any characteristic of the toll circuit makes balancing or equalizing difficult, the 2850-cycle or 2450-cycle filter is used.

One of the features provided by the Type 47 Two-Wire Repeater is the automatic alarm and by-pass control. In the event of an amplifier tube failure or power supply interruption, an alarm is given and a circuit around each amplifier is automatically established. When one amplifier fails it is desirable, for psychological reasons, to by-pass both amplifiers in order to maintain the same conversation level at each end of the toll circuit. Although the transmission level is reduced due to the amplifiers being cut out of the circuit, conversation is still possible. The equalizers are also by-passed because of their inherent loss which is normally offset by the amplifiers. Since by-passing the amplifiers eliminates the feedback loop,

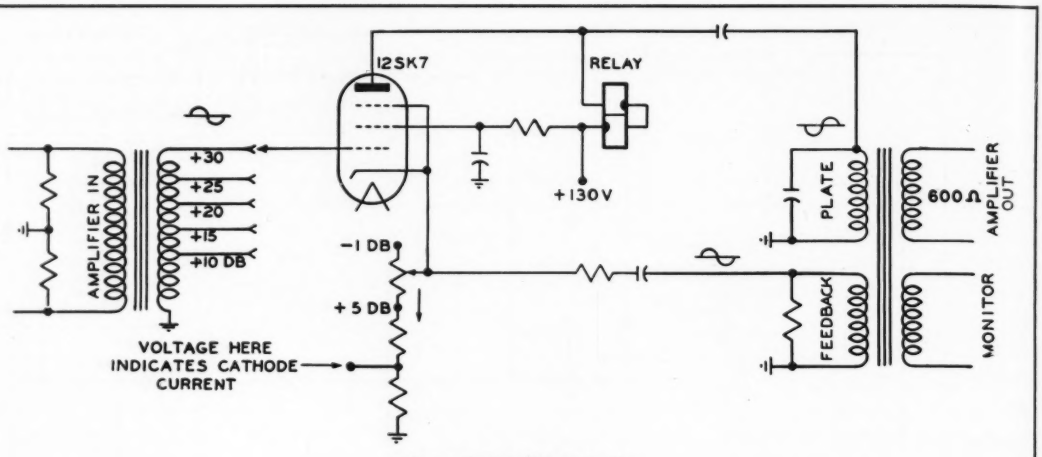


Figure 8. Amplifier circuit.

line balancing is not necessary, and consequently the filters can also be by-passed. Thus the by-pass circuit eliminates all components between hybrids. In a two-wire repeater, two control relays (one in each line and line balancing unit) are normally held in the operated position by an alarm relay in each of the amplifiers. Figure 7 illustrates this circuit arrangement. When either amplifier fails, its alarm relay will allow the cut-out control relays to release and connect the by-pass circuits. The amplifier relay gives an alarm so that the trouble can be located and corrected. Power for the cut-out control relays can be taken from the repeater power supply, or from an exchange battery.

Amplifier Unit

The Type 47 Repeater includes a unit made up of two amplifiers which are mounted on a 3½-inch panel. Each amplifier is a single stage, negative feed-back type with transformer coupled input and output, both matched to 600 ohms, substantially non-reactive. The schematic circuit is shown in Figure 8.

Impedance coupling is used with a type 12SK7 tube and the plate inductor consists of a relay which is held in the operated position by the plate current. The two relays in each amplifier unit are arranged so that when the current in either amplifier is interrupted the corresponding relay releases, giving an alarm. In addition, it releases the cut-out relays in the associated line and line balancing units. Both amplifiers are then eliminated from the circuit, as mentioned before.

The gain of each amplifier is variable from 10 to 35 decibels. Steps of five decibels each are provided by plug-in connections to five taps on the secondary of the input transformer. Continuous control over a range of six decibels is obtained by the use of a rheostat in the cathode circuit. The tap selecting assembly and vernier gain control for both amplifiers appear on a small sub-panel at the front of the unit. The taps and the vernier control scale are marked in decibels showing the gain of the amplifiers; the accuracy of calibration is within one decibel.

Current feed-back is provided by an un-by-passed cathode resistance. A separate winding on the output transformer is connected, degeneratively, through a resistance-capacitance network to the cathode resistance. Varying the vernier gain control changes the values of current feed-back, voltage feed-back, and cathode bias in such a way as to control the gain and to maintain the output impedance at the nominal 600 ohms.

The maximum undistorted output for all settings of the vernier gain control is 2.45 volts, or +10 decibels (reference level: 1 mw-600 ohms). The input level may be as high as 1.3 volts, or +4.5 decibels. The frequency response is uniform from 300 to 3000 cps.

The cathode current of each amplifier tube can be checked by measuring the voltage across

a calibrated resistor which is part of the cathode resistance. Connections are made on the jack panel.

Jack Panel and Power Supply Unit

Facilities for making various types of performance tests during installation and maintenance are provided on a jack panel. This panel, occupying 1¾ inches of vertical space, is combined with power supply equipment to make up one unit of the Type 47 Repeater. This dual unit provides testing facilities and power for either one or two repeaters, and can be used for two-wire or four-wire applications.

The power supply is arranged to operate from a 105- to 125-volt, 50/60 cycle a-c source. Tap connections on the primary and plate windings of the transformer provide means for adjusting the plate and filament voltages to their proper values. A full wave, selenium disc rectifier, using the low voltage, long life discs, provides 130 volts d-c at 70 ma. for the plates of the amplifier tubes and for operating the cut-out relays, as shown in Figure 7. A two-section filter using choke input and oil filled capacitors reduces the ripple voltage so that no audible hum is introduced into the line by the a-c operated repeater. The 12SK7 tubes of the amplifier units are heated in series from a 24-volt winding on the power transformer. Two on-off toggle switches are provided on the jack panel—one for each of the amplifier units. Approximately 12.5 watts of power are required to operate each repeater. The power supply voltages are standard and may be supplied by batteries in large installations.

Line Terminating Unit

The *line terminating unit* consists of a resistance hybrid, compromise balancing network, blocking condensers and a by-pass relay, all of which are mounted on a 1¾ inch panel.

The resistance hybrid is a four-branch lattice type network which terminates the amplifiers and switchboard drop in 600 ohms. Its loss in both directions is 10.7 decibels, compared to three decibels for the coil type hybrid, but the amplifier has ample gain to offset the additional loss.

Since the impedance of the drop circuit may vary over a wide range, a compromise balancing network consisting of a 2-mf. condenser connected in series with a 600-ohm resistor is used. An external balancing network can be used if necessary, and connections are made at the rear terminal block.

Because of the relatively low net gain at terminal repeaters, the filter and equalizers are omitted.

The line terminating unit can be used for the purpose of terminating four-wire circuits as well as two-wire circuits.

Four-Wire Line Unit

Two groups of identical components, one for each direction of transmission, make up the *four-wire line unit*. Included in each group are line matching repeating coils, equalizers, and a filter. The vertical rack space required for mounting this unit is 3½ inches. The repeating coils and filter are the same as those used in the two-wire repeater. However, due to the wider spacing of four-wire repeaters, more frequency distortion per repeater section results. Resistance-capacitance equalizers alone do not provide the necessary equalization, so an inductance is included in the equalizer arrangements, as shown in Figure 9.

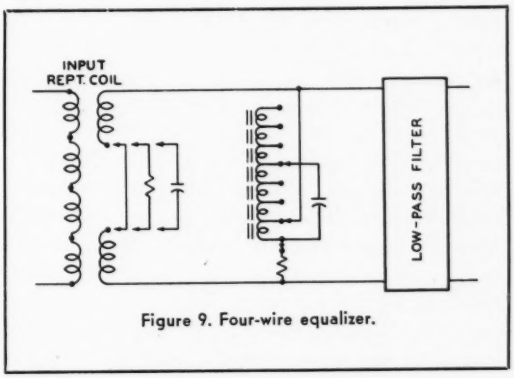


Figure 9. Four-wire equalizer.

A toroidal coil with several taps provides a variable inductance which is parallel-resonated by means of a condenser at appropriate frequencies above 1000 cycles. A resistance-capacitance network similar to that used in the two-wire repeater is also provided for controlling the attenuation of frequencies below 300 cycles. Equalizing adjustments are made on the front terminal panel.

This unit includes the necessary equipment for the line sides of two four-wire terminal repeaters. Line terminating units with their resistance hybrids are used on the drop sides of four-wire terminal repeaters.

By-passing the amplifier in a four-wire repeater is not practical because of the relatively high gain employed. In most cases, cutting out and by-passing a repeater on a four-wire toll circuit reduce the transmission level to a point where conversation would be impossible. Therefore no cut-out relays are provided on the four-wire unit, and the relays in the amplifiers are used only for giving an alarm when the power supply or tubes fail.

Signaling

Signals at 1000 cycles can be passed through the voice transmission paths and amplified in the same manner as a voice signal. Signals at 135 cycles can be amplified, but are usually repeated by means of separate units which are connected at the rear terminal block. Signals at 20 cycles can pass through the 20-cycle by-pass circuit within the repeater. On long lines it is necessary to repeat 20-cycle signals by means of ringing repeaters. Signals at 3½ cycles and simplexed d-c signals can also be by-passed within the repeater. Retard coils in the line and line balancing units are provided for these by-passing requirements. The various arrangements are made by strapping connections at the terminal panel at the front of the unit.

AUTOMATIC ELECTRIC'S TYPE 48 BATTERY ELIMINATORS

By O. D. GRANDSTAFF

SYNOPSIS: *Field of application for telephone battery eliminators—regulation characteristics — physical designs of cabinet and panel models—regulation principles — line voltage compensation — performance data.*

THE Telephone Battery Eliminators described herein are complete power units designed to deliver smooth, quiet d-c power from a commercial a-c source. Such units can be used in place of storage batteries and associated charging equipment in many installations, thereby saving in initial cost and maintenance of storage batteries. Where, as in the case of public telephone central offices, the d-c operated equipment requires maximum continuity of power, a storage battery is usually needed to provide a standby d-c source since, in the event of commercial power failure, increased dependence must be placed on communications. But private automatic exchanges and many other types of switching systems requiring a noise-free d-c source can be successfully powered with battery eliminators operated from the dependable commercial a-c power now available in most communities.

Type 48 Telephone Battery Eliminators provide steady power having characteristics very much like those of a battery floated from a constant voltage charger. They are available with outputs of 25 and 50 volts, each with a rating of either 3 or 6 amperes. Complete compensation for line voltage variations within 10% of normal is provided. The d-c output voltage is practically constant from no-load to full-load, and momentary peak loads up to 150% of the name plate rating can be met with less than 4% deviation. Compensation for both power line voltage and load variations is extremely rapid due to the principle of operation employed.

A Type 48 Battery Eliminator is illustrated in Figure 1. The cabinet design is the same as that used for Automatic Electric Company's selenium disc battery chargers (Convotrols). Covers are finished in baked grey enamel and the frames in black rubber japan. The welded frame extends below the bottom of the unit to provide feet which hold the eliminator far enough off the floor to allow ample cooling air to enter the bottom grill. The feet and back panel are drilled to meet the requirements of either floor or wall mounting.

Panel models, shown in Figures 2 and 3, also are available. These can be mounted on relay racks, along with relay strips or other rack-mounted apparatus, so that all the equipment is contained in a common assembly. Components of the panel models are the same as for the cabinet models, except for the control panel equipment which is omitted.

The control panel on cabinet models is equipped with a volt-meter, ammeter, and "on-off" toggle switch. These are the only controls required except for a tap switch inside for making aging adjustments. This switch is located between the two fuse blocks and is advanced one or two steps during the first two or three years' use of the eliminator to compensate for aging of the dry disc rectifiers. After that, very little change in characteristics will occur since the rectifiers age most during this initial period.

Construction details of the eliminators are shown in Figures 1, 2 and 3. All essential parts are mounted on heavy flanged panels for ease of assembly and wiring. Frames for cabinet models are bolted to the back panel after wiring is completed. All transformers and chokes are bakelite impregnated, and all wiring is asbestos insulated to insure good insulation throughout the eliminator's characteristically long life. The rectifier stack and electrolytic filter capacitors are located at the bottom of the panel, near the grill, where the coolest air flows over them.

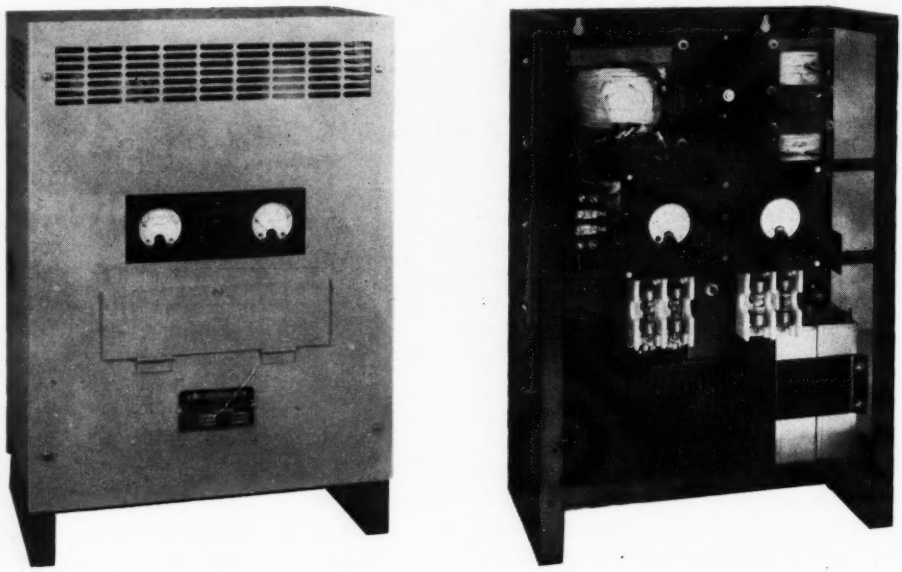


Figure 1. Type 48 Battery Eliminator. Left, with cover in place. Right, with cover removed.

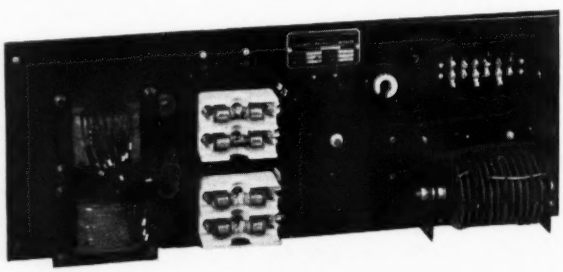


Figure 2. Panel type mounting. Front view.

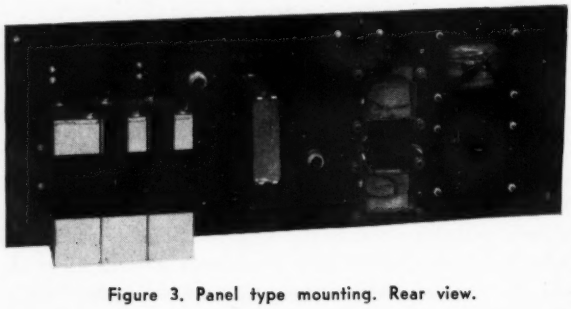


Figure 3. Panel type mounting. Rear view.

Principle of Operation

The Type 48 Battery Eliminator uses a new principle of operation which results in a very stable output voltage. This principle affords very rapid regulation, since all compensation is achieved in the two input transformers, thus avoiding delays inherent in circuits using inductive control windings. Such speedy compensation is particularly desirable in eliminators to reduce momentary voltage fluctuations when large shifts of load occur. The principle of operation involves successive changes from single-phase power to two-phase, to three-phase, and then rectification to give d-c power

output. At no-load the output is rectified single-phase power, while at maximum load the d-c output is rectified three-phase power resulting from the above conversions.

The advantages of changing from single-phase to three-phase are illustrated in the empirical curves of Figures 4 and 5, which show the characteristics of single-phase and three-phase selenium rectifiers. Note that for a given a-c input voltage —for example, 16 volts—the full-load d-c voltage of the three-phase rectifier is higher than the no-load d-c voltage of the single-phase rectifier with the same 16 volts a-c input. This characteristic enables the eliminator to provide a constant output voltage from no-load to full-load by a gradual change from single-phase to three-phase as the load increases.

The change from single-phase to three-phase is caused by the load itself which divides between the two transformers shown in Figure 6. The main transformer, having a conventional silicon-iron core, is operated at high saturation while the teaser transformer, having a silicon-iron core with fixed air gap, never saturates. An oil-filled capacitor of the power-factor-correcting type is connected across a winding of the main transformer, but because of the high saturation of the transformer, the combination is an inductive reactance at no load. The teaser transformer, with its air gap, is also an inductive reactance.

As shown in Figure 6, the primaries of the two transformers are connected in series and to the a-c power supply. At no-load, the voltages on both transformer primaries lead the common primary current by approximately 90°; therefore the secondary voltages are approximately in phase. An increasing load on the main transformer causes demagnetization of its core. This greatly reduces its core saturation, because the operating point is at the knee of the magnetization curve, and increases the inductive impedance.

The transformer and capacitor combination changes to a capacitive reactance when the inductive reactance reaches an impedance higher than that of the capacitor. The capacitive reactance of the combination and the inductive reactance of the teaser transformer are so chosen as to magnitude that their values are numerically equal to the portion of the resistance of the load

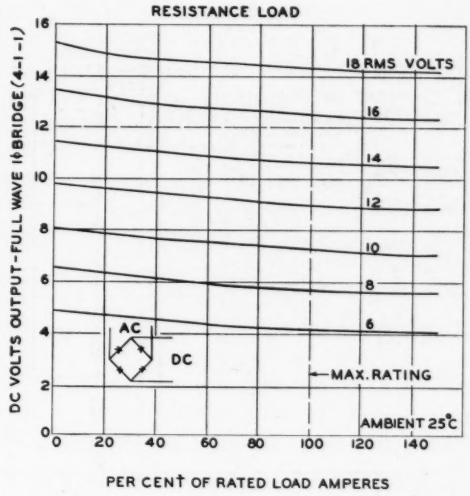


Figure 4. Load characteristics of single-phase selenium rectifiers. (Courtesy of General Electric Company, Lynn, Mass.)

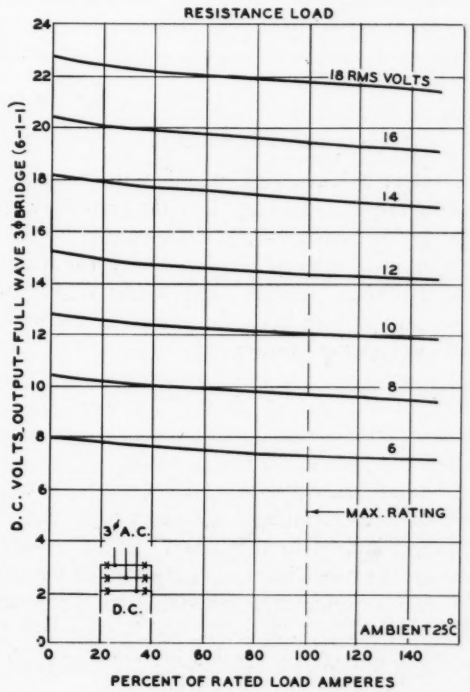


Figure 5. Load characteristics of three-phase selenium rectifiers. (Courtesy of General Electric Company, Lynn, Mass.)

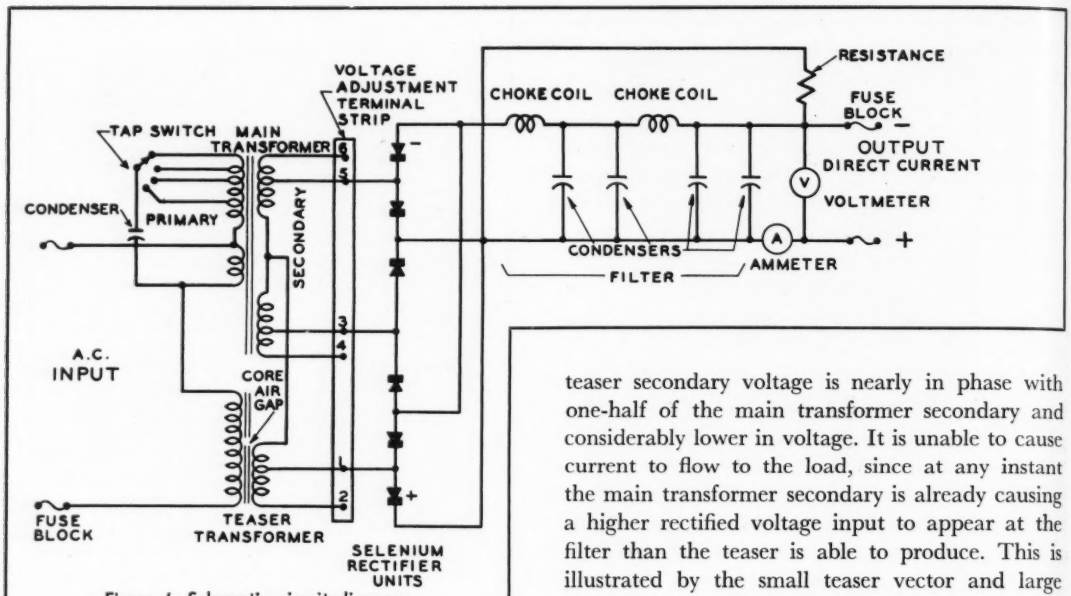


Figure 6. Schematic circuit diagram.
(Licensed under U.S. Patent 2,209,948, owned by Westinghouse Brake & Signal Co., Ltd., Chippenham, Wilts., England.)

coupled through the rectifier to the transformers when maximum load is reached.

At the maximum load condition, the main transformer secondary voltage lags the secondary current by 45° (or lags the primary current by 225°) as a result of the combination of the reactive current and load current. The teaser transformer secondary voltage leads the secondary current by 45° (or lags the primary current by 135°). Thus, the voltages on the two transformers are 225° - 135°, or 90° out of phase. Therefore, the secondaries provide two-phase power. The teaser transformer secondary has a voltage, at maximum load condition, equal to 0.866 of the main transformer total secondary. By connecting the secondary windings in the "Scott" or "T" connection as shown in Figure 6, the two-phase power of the two secondaries is converted to three-phase power at points 1, 3 and 5, which are connected to the input of the three-phase rectifier stack.

Note that the top four sections of the rectifier in Figure 6 form a full-wave, single-phase bridge which is connected to the main transformer secondary and to the filter and load. At no-load the teaser secondary voltage is nearly in phase with one-half of the main transformer secondary and considerably lower in voltage. It is unable to cause current to flow to the load, since at any instant the main transformer secondary is already causing a higher rectified voltage input to appear at the filter than the teaser is able to produce. This is illustrated by the small teaser vector and large main vectors in Figure 7-A. As the load increases to half-load, the main transformer secondary voltage vector approaches 90° to the teaser transformer vector (40° as shown in Figure 7-B) and the teaser voltage increases in magnitude. Figure 7-C shows the secondary voltage vectors 90° out of phase and the teaser vector increased to a value of 0.866 of the total main transformer secondary voltage. An equilateral triangle is formed by joining the extreme ends of the vectors (Figure 7-D). This represents a true three-phase balanced circuit which gives maximum output.

Any further loading causes the angle between the vectors to increase to more than 90°, causing a deviation from the balanced three-phase condition which results in a rapid decrease of output voltage as shown in Figure 8. The load at which the three-phase condition is reached and the output voltage begins to drop is dependent on the a-c line voltage. A higher line voltage causes the optimum three-phase condition to occur at a higher load.

Line Voltage Compensation

Compensation for line voltage variations is accomplished by rotation of the main transformer secondary voltage vector with respect to the teaser vector. A low line voltage decreases saturation of the main transformer core, causing an increase in its inductive reactance. The resultant impedance

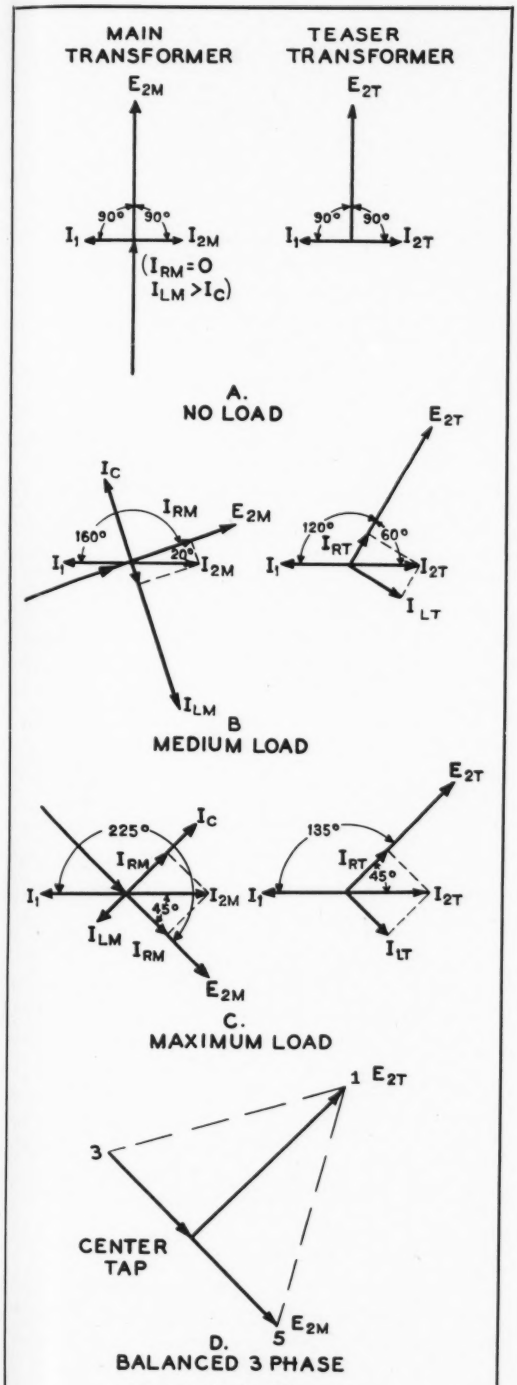


Figure 7. Vector Diagrams.
(For key to symbols see bottom of adjoining column.)

of the main transformer and capacitor combination becomes more capacitive while the teaser transformer remains at the same impedance. Thus, low line voltage causes the main transformer voltage vector to rotate clockwise. This improves the three-phase relation which compensates, or at some loads even over-compensates, for low line voltage. High line voltage causes greater saturation of the main transformer. Its voltage vector rotates counterlockwise, making the secondary voltages more nearly in phase. Thus the imput to the rectifier stack departs from the three-phase condition, and thereby compensates for abnormally high line voltage.

Low line voltage and increasing load both cause clockwise rotation of the main transformer vector towards the 90° position. This causes the optimum three-phase condition to be reached at a load lower than normal. This is illustrated by the 105-volt curve of Figure 8 at 150% load. High line voltage causes the main vector to rotate slightly counterclockwise while increasing load causes clockwise rotation, resulting in the optimum three-phase condition at a higher load, as illustrated by the 125-volt curve.

Performance Curves

The output voltage regulation curves for both the 25-volt and 50-volt eliminators are shown in Figure 9. Note that the voltage is very steady out to 150% of rated load. It is free of ripple due to the two stage filter. Ripple frequencies are 120 cycles at no-load and 360 cycles at maximum load, with a mixture of the two at intermediate loads.

I_1 = input current (common to the primaries of the two transformers).

E_{2M} = voltage of main transformer secondary.

E_{2T} = voltage of teaser transformer secondary.

I_{2M} = current of main transformer secondary ($I_C+I_{LM}+I_{RM}$).

- **I_C = capacitive current of capacitor referred to main transformer secondary.**
- **I_{LM} = inductive current of main transformer primary referred to its secondary.**
- **I_{RM} = resistive current of load in main transformer secondary.**

I_{2T} = current of teaser transformer secondary ($I_{LT}+I_{RT}$).

- **I_{LT} = inductive current of teaser transformer primary referred to its secondary.**
- **I_{RT} = resistive current of load in teaser transformer secondary.**

NOTE: Transformer losses are omitted to simplify diagrams.

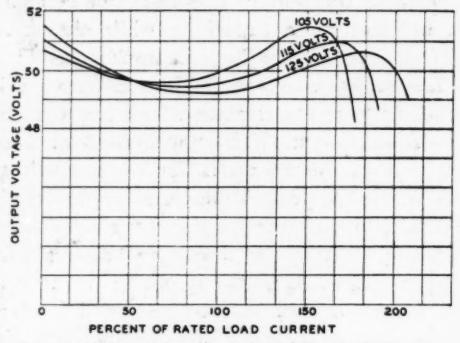


Figure 8. Load characteristics of Type 48 Battery Eliminator.

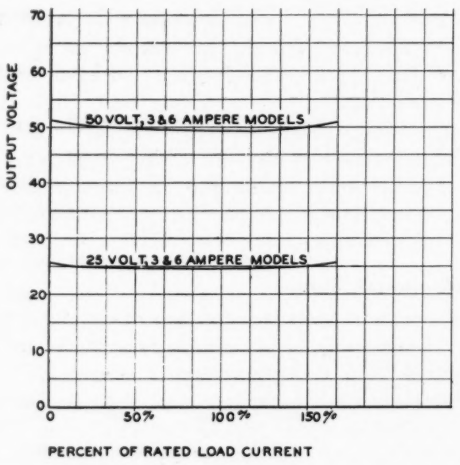


Figure 9. Voltage regulation characteristics.

The higher ripple frequency from the three-phase rectifier facilitates the filtering. Although the regulation and filtering are satisfactory above 100% of rated load, continuous loads should be kept within the rating to prevent excessive rectifier aging. The good regulation out to 150% of rated load provides the necessary reserve power comparable to that furnished by a battery in a battery-and-charger installation.

Figure 10 illustrates the efficiency and power factor curves. Eliminators of the same output voltage but different current ratings have the same characteristics. The efficiency is low at light loads, due largely to the losses in the main transformer

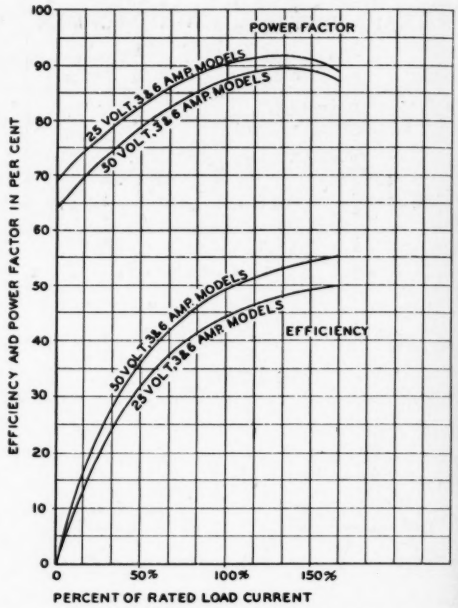


Figure 10. Efficiency and power factor characteristics.

which is at highest saturation at no load. The 50-volt models are more efficient than the 25-volt models, especially at high loads, because the power loss in the filters of both is the same for like load currents, resulting in a proportionately greater loss for the low voltage models. The power factor of each model is very good, starting at about 70% and rising to 90%. Maximum power factor occurs at 140% of rated load which is near the point where balanced three-phase operation is reached.

Overall operation of the Type 48 Battery Eliminator is very satisfactory, since it automatically maintains a practically constant output voltage without attention. These eliminators are particularly advantageous in installations where trained maintenance employees are not regularly available.

References:

"Constant Potential Rectification", Descriptive Pamphlet No. 11L, *Westinghouse Brake & Signal Co., Ltd.*, Chippenham, Wilts., England, April, 1940.

"A Constant Potential Power Unit", S. Mulhall, *The Telecommunications Journal of Australia*, February, 1940.